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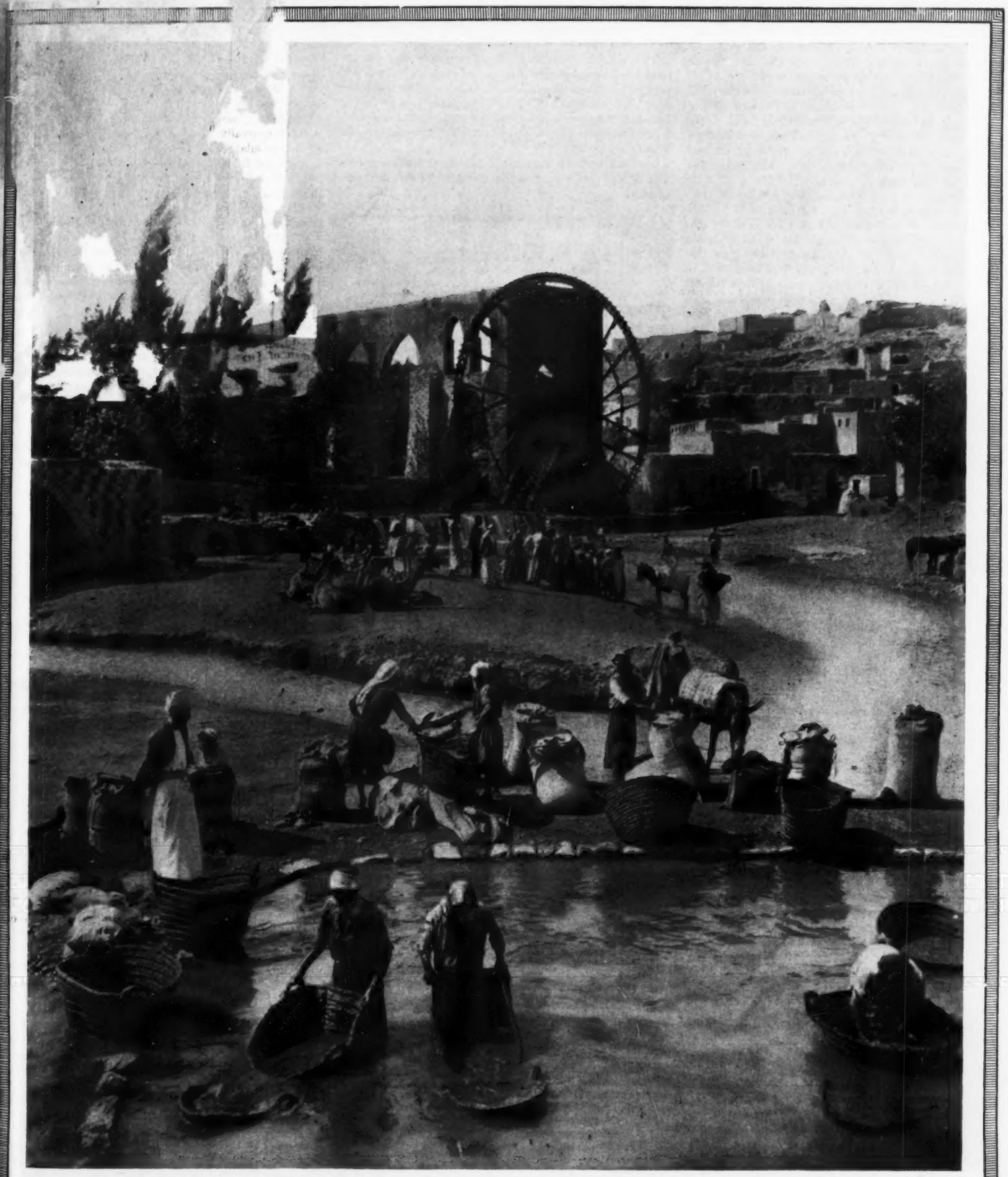


The Wheels are Driven by the Flow of the Orontes River. There are Four of These Used for Pumping Water for Irrigation.

THE SEVENTY-FOOT UNDERSHOT WATER WHEEL AT HAMA, NORTHERN SYRIA.—[See page 213.]

The Chemical Engineer and Industrial Efficiency*

His View of Manufacturing Economics

By W. M. Booth

THE chemical engineer can take his legitimate place n industrial affairs only when he begins to concern himself with values and returns and can transpose the signs and symbols of the chemist to the dollars, cents and percentages of the business world. The profession must necessarily include men with diversified mental attributes, experiences and education. Natural inventors, builders, executives, analysts and economists are examples of the men who will choose this branch of engineering as a life work.

The first and highest type of endeavor concerns itself with the invention of new processes and the perfection of these, later establishing useful industries. Relatively few men have the ability, courage and means to embark in totally new enterprises, and the larger percentage of those who do so, fail, because these three important elements are not properly balanced.

Not less important, but demanding a different type of mind, perhaps more strongly analytical in its nature, is the large and ever-increasing field open to those who are able to improve or effect economies in the processes of firms already established. Closely related to this is the examination of new enterprises that seem to have merit and which need scientific assistance and capital for development. No greater damage has ever been wrought on American investors by any class of men than by the "new chemical," "private," or "secret process" promoters who have used the subtleties of the science as a basis for fraud.

Irrespective of the particular division of endeavor undertaken, the chemical engineer must fortify himself against all classes of misrepresentation, and must concern himself with questions of process, cost, market, location and actual capital needed in any new industrial enterprise. No considerable investment should ever be made without a complete report from conservative men, who are familiar with the industry involved.

While the basic operations of activity include agriculture, mining, transportation and manufacturing, the last is chosen as best exhibiting the use of the chemical engineer along the lines previously pointed out.

Those who have made a careful study of the splendid papers of Dr. Munroe[1] and Dr. McKenna[2] to be found in the proceedings of this Institute have been impressed with the fact that nearly all of the manufacturing of the United States is carried on east of the Mississippi River, and that more than one third of this is confined to New York, New Jersey and Pennsylvania. The following census report shows the increase in capital and people employed from 1850 to, and including, 1909:

	Capital invested in manufacturing	Employees
1850	$ 533,245,000	957,059
1860	1,009,856,000	1,311,246
1870	1,694,567,000	2,053,996
1880	2,790,273,000	2,732,595
1890	6,525,051,000	4,251,535
1900	9,813,834,000	5,306,143
1910	18,428,270,000	6,615,046

It will be seen that the investment at the last date amounts to eighteen billion dollars and the number of employees to over six millions. To maintain the almost perpendicular increase in our manufacturing activities is the duty of the commonwealth, for no more useful type of industrial activity can be found, especially when our products can be placed in foreign markets at a profit.

The observations covered by this paper are necessarily personal and have accumulated during twenty years, ten of which have been devoted mainly to the questions now to be discussed. The observations cover fifty-three "going" plants, representing thirty-seven industries, and some others that have never gone further than a prospectus distributed by an ignorant or a dishonest promoter. Obviously, in a paper of this kind, a general outline only can be given.

In looking back over the years covered, it would seem as though the period has been one of unexpected crises, rising wages, unsettled market conditions, and acute competition. Among the fifty-three concerns above mentioned, there have been eight failures, two have withdrawn from business, and one, only, has burned. The remaining industries are owned as follows:

Private	11
Corporations	19
Trusts	12

The failures were attributed to the following causes:

Two to incorrect conceptions of the costs and profits of a business.
Two to dishonest employees.
Two to incompetent supervision.
One to insufficient working capital.
One to manipulation of the stock in New York City in 1907.

The superintendents of twenty plants have been forced out or discharged for reasons such as inattention to duty, incompetency, lack of knowledge of the business, trust management, the introduction of new methods, inability to pay dividends on inflated stock issue, dissension among officers of the company or inability to handle help.

As I understand the matter, a general efficiency survey of any business must recognize the following conditions:

EXTERNAL

Policy of the government toward an industry. Capital upon which dividends must be earned.
Location.
Cost of plant and equipment.

INTERNAL

Unit cost of finished product, subdivided as follows:

Raw materials	Supplies	Fixed charges
Labor	Office expenses	Interest
Power	Repairs	Depreciation
Lighting	Sales	Insurance
Heating	Advertising	Taxes
Cartage, freight and express	Charity	

Considering the capital invested, and the importance of the manufacturing business to all the people, laborers, tradesmen and stockholders, the Government is bound to respect, foster and protect these interests at all times. It would manifestly be suicidal to introduce any highly protected industry into the United States pending our tariff changes.

The passing of the pioneers who built and operated our first mills has thrown the responsibility of ownership upon the shoulders of many men totally unfitted by experience or temperament to carry on the business. To add to this misfortune of inheritance, all basic industries have expanded enormously, requiring more capital than one family or group of men could furnish. This led to the general adoption, between 1880 and 1900, of the corporate idea. While of the greatest value as an industry builder, no more pernicious influence has entered the manufacturing business than this conception and use of an artificial individual without responsibility.

Abundance of money in the banks, the abuse of personal credit, and easy bankruptcy laws have made it possible to squander the public's money without scruple. In several instances in my experience, good operating managers have attempted to maintain their profits on an inflated and unwarranted stock issue, and have failed. Good men, improved machinery and low operating costs cannot offset unnatural overhead expense. "Good will" has no place on the balance sheet of a well regulated and solvent business. Any venture in the elaboration of raw materials ought, when brought to a paying basis, to be able to return to the stockholders a net profit of at least 10 per cent. Some old established lines of business net from 20 to 60 per cent annually, and two good years have often paid for plant and equipment complete. Government statistics of manufactures included in the Thirteenth Census reports show the average net returns, for the year 1909, on thirty-nine of the principal manufactures in this country (see table).

	Per cent.
Printing and publishing	20.33
Agricultural implements	11.09
Automobiles, including bodies, etc.	22.03
Boots and shoes	15.47
Brass and bronze products	12.25
Bread and other bakery products	25.85
Butter, cheese and condensed milk	23.23
Canning and preserving	13.09
Carriages and wagon and material	12.14
Chemicals	15.45
Clothing, men's, including shirts	20.29
Clothing, women's	33.03
Confectionery	23.12
Copper, tin and sheet iron	10.72
Cotton goods, etc.	8.66
Flour mill and grist mill products	16.32
Foundry and machine shop products	10.23
Furniture and refrigerators	11.66
Hosiery and knit goods	15.42
Iron and steel, blast furnaces	5.90
Iron, steel, steelworks, etc.	9.38
Leather goods	16.73
Leather, tanned, curried and finished	6.75
Liquors, distilled	12.83
Liquors, malt	10.68
Lumber, and timber products	13.82
Marble and stone works	15.87
Oil, cotton seed and cake	12.04
Paint and varnish	13.40
Patent medicines, etc.	28.28
Petroleum, refining	8.24
Silk, etc.	13.18
Slaughtering and meat packing	15.02
Smelting and refining copper	23.25
Smelting and refining lead	5.29
Sugar and molasses (not beet sugar)	7.15
Tobacco manufactures	20.71
Woolen, worsted and felt goods, etc.	10.98

Considering now the matter of location, the manufacturer generally follows his market. As the growth of the population of the United States is westward, it has been found expedient to move whole industries from Massachusetts and New York to Michigan, Illinois and Missouri. Relocation of furniture and wagon plants has been quite general, because it has been found cheaper to ship the finished product to the markets than to bring the raw material east. Changes in market conditions have compelled the agricultural implement manufacturers to locate in the middle West. Formerly the manufacture of shoes was a Massachusetts industry; now, whole towns in New York and Missouri are devoted to this business.

No better illustration of economic change can be cited than the conditions at my own birthplace, a valley so[illegible]ca, N. Y. On a stream furnishing from 60 to 120 horse-power at each plant, sixteen mills were in operation from 1873 to 1885. These employed about 2,000 people. Forks and hoes were made in two plants, wagons in one, woolen cloth in two, cotton cloth in five, knit goods in one, silk in one, paper in two, and sewing machines and mowing machines in one. The movement of freight and finished products kept the railroad and scores of teams busy. Furnishing provisions for the employees in the mills afforded a living for many tradesmen.

One agricultural implement plant was burned; one was bought by a trust and closed; the paper mills have been idle for years; three cotton mills have gone out of business; one woolen mill was burned and the other was closed; the knit goods plant and the machinery plant burned; and the silk industry was moved to Philadelphia. To-day, there are only three really good companies operating in the valley. Originally humming with the whirr of spindles and clicking with the throw of the shuttles in the looms, the valley is now quiet, and agriculture is the main business. Those of us who lived there did not know why so many fires took our industries away. It was observed that no factories were rebuilt. I now know that it no longer paid to make woolen and cotton cloth, to spin silk, and manufacture paper in that locality. The peculiar elements which we term economic conditions took our prosperity away, with incalculable loss to all concerned, stockholders, employees and tradesmen alike. The moss-grown walls to be seen on many swiftly moving streams are monuments that mark industrial change.

Capital is sometimes invested in new projects, the aim of which is the use of raw materials that are supposed to be abundant, but that are later found to be insufficient in quality or quantity. Cement plants along the Erie Canal in New York State represent this class and also illustrate the rapid changes that may enter the elaboration of a product. In this instance the use of shale rock has taken the place of marl and clay in the manufacture of cement.

Beet sugar factories were started at Lyons, Binghamton, and at Rome, N. Y. The cost of the plant in each instance was very large, people cheerfully investing their money and expecting unusual returns. After several years of failure and loss the entire project has been given up; the empty buildings now remain after an expenditure of not less than $2,000,000. Colorado and California produce beet sugar at a profit. The location of the industry in New York State was a mistake, but the stockholders had to learn this. In the meantime, canning factories have sprung up throughout central and western New York and the well managed ones are in a flourishing condition. Cheap raw materials, plenty of help, excellent transportation facilities and a ready market are contributory causes to its success.

No science or art can determine with accuracy whether economic conditions are correct for the location of an industry. Accident or good business judgment may accomplish what statisticians and scientists cannot.

COST OF PLANT AND EQUIPMENT.

With plenty of money at his disposal, the optimistic

* Paper presented at the Fifth Annual Meeting of the American Institute of Chemical Engineers, Detroit, December, 1912, and published in the *Journal of Industrial and Engineering Chemistry*.

[1] "The Chemical Industries of America," Charles E. Munroe, *Trans. Am. Inst. Chem. Eng.*, 2, 84.

[2] "The Centering of Great Industries in the New York Metropolitan District," Charles F. McKenna, *Trans. Am. Inst. Chem. Eng.*, 2, 65.

manufacturer is apt to spend too great a portion on buildings and equipment. Ample working capital should always be held in reserve. The amount thus employed will necessarily vary with the business, but from 25 to 50 per cent is commonly set aside for this purpose in smaller industries, the capitalization of which is from $50,000 to $200,000.

It is much better to build a plant in a modest way, anticipating growth, than it is to find capital for running a concern in the midst of business expansion; especially so, if stockholders have had to wait from three to five years without dividends.

Again, a very expensive plant may be erected with consequent large overhead expense, where the income does not warrant the outlay. I found it impossible to recommend the erection of a water-gas plant in a town of 3,500 people. A canvass of all prospective users showed that not more than two or three per cent income could be expected. A similar plant in a town of about this number of people can positively pay no more than two per cent on the investment after all avenues for gas consumption have been thoroughly exploited.

LOCATION.

To aid those who wish to study the problems concerning location, I have made a list of the elements that seem important. These are as follows:

Accessibility of raw materials	Climate
Market	Hygienic conditions
Transportation	Taxes
Labor	Insurance
Power	Banking facilities
Water	Heating
Supplies	Lighting

Obviously, all of these details cannot be discussed in a general paper. The importance of one item, water, requires special consideration, and shows very clearly how carefully capital should investigate a new location, when the growth of a business warrants a change or when misfortune requires it.

With a favorable location, a demand for the product, an honest stock or bond issue, a modest initial outlay for buildings and equipment, and sufficient capital for doing business, an executive should earn a fair dividend on the investment.

INTERNAL UNIT COST.

The ideal is the basis of our best effort everywhere. In manufacturing, this ideal is approached when the largest quantity of good goods is turned out at the lowest possible cost. To determine how to attain the above conditions is the duty of every executive. But the task is not a simple one, for bookkeepers are not statisticians, and although all of the data necessary in connection with the proportioning of expense in the manufacture of an article may be derived, it takes a large amount of study to draw correct conclusions. No simpler expedient in my estimation has been devised in this connection than unit cost. What does it cost to produce a pound, a horse-power, a barrel, a yard, or a machine, any single article, many of which are made each month or year? These items may be apportioned as percentages. The separate items under fixed and operating expense become factors of the total. As an example, we will say that the production of a machine has entailed an outlay of $25.00 and that this is divided as follows:

	Per cent.		Per cent.
Raw materials	20	Repairs	1.3
Labor	40	Sales	10
Power	7	Advertising	5
Lighting and heating	1	Charity	0.2
Transportation	3	Interest, depreciation,	
Office expenses	2.5	taxes and insurance	10

This outline shows at a glance that labor is a large item in the cost of this article and that any economy that can be effected in this department will make an appreciable saving in the total outlay.

By courtesy of Mr. E. Durand, Bureau of Census, I am able to present a table illustrating the method above outlined. (See the second column on this page.)

This is a valuable guide in any efficiency study of production costs, although too many items are grouped under expense, which may be used by any executive to conceal exorbitant bills of any nature.

The actual cost of a case of tinned goods of the season of 1912 is divided as follows:

	Per cent.		Per cent.
Raw materials	30.40	Interest	1.90
Labor	14.40	Depreciation	1.80
Fuel	0.17	Taxes and insurance	1.60
Freight and express	0.04	Boxes and labels	7.30
Maintenance	4.80	Loss on seed	5.80
Sales	3.90	Discount and brokerage	3.10
Advertising	0.90	Expense	8.70

The remaining items are not considered useful in this paper. The tin container itself includes a cost of 85 per cent for materials and 15 per cent for labor.

STATISTICS OF MANUFACTURE. THIRTEENTH CENSUS, 1910, PAGE 30

Industry	Per cent. of Total Expenses Reported: Salaries	Wages	Materials	Miscellaneous expenses
All industries	5.1	18.6	65.8	10.5
Agricultural implements	8.6	24.3	51.1	16.0
Automobiles, including bodies and parts	4.5	23.1	62.5	9.9
Boots and shoes, including cut stock and findings	3.9	20.6	69.6	5.9
Brass and bronze products	4.1	17.3	72.6	6.0
Bread and other bakery products	4.0	17.4	69.9	8.6
Butter, cheese and condensed milk	1.4	4.3	91.0	3.3
Canning and preserving	5.6	13.5	72.0	9.0
Carriages, wagons and materials	5.7	27.0	58.9	8.4
Cars, general shop construction and repairs by steam R. R. companies	4.3	44.7	49.2	1.8
Cars, steam railroad, not including operations of R. R. companies	4.3	23.0	66.7	6.0
Chemicals	6.5	15.0	68.2	10.3
Clothing, men's, including shirts	5.2	20.7	57.9	16.2
Clothing, women's	6.0	23.0	61.1	9.9
Confectionery	7.6	13.1	67.9	11.4
Copper, tin and sheet iron production	5.8	22.4	63.7	8.1
Cotton goods, including cotton small wares	2.6	24.0	66.9	6.5
Elect. mach., apparatus and supplies	10.0	24.5	53.8	11.7
Flour mill and grist mill products	1.5	2.6	92.8	3.1
Foundry and machine shop production	8.7	29.8	50.1	11.4
Furniture and refrigerators	7.3	30.8	51.0	10.9
Gas, illuminating and heating	10.9	18.4	46.2	24.5
Hosiery and knit goods	4.4	25.5	62.7	7.4
Iron and steel, blast furnaces	1.8	6.8	88.4	3.0
Iron and steel, steel works and rolling mills	2.9	18.3	73.9	4.8
Leather goods	7.2	19.3	64.6	8.9
Leather, tanned, curried and finished	2.2	10.5	81.2	6.1
Liquors, distilled	1.0	1.6	18.4	79.0
Liquors, malt	7.6	13.7	32.2	46.5
Lumber and timber products	4.8	32.0	51.0	12.2
Marble and stone work	6.7	44.8	39.4	9.1
Oil, cottonseed and cake	3.1	4.3	87.7	4.9
Paint and varnish	9.3	7.4	71.1	12.2
Paper and wood pulp	4.0	17.2	69.7	9.1
Patent medicines, compounds and druggists' preparations	14.9	8.7	44.1	32.4
Petroleum, refining	1.8	4.4	89.6	4.2
Printing and publishing	16.7	26.6	32.6	24.1
Silk and silk goods	4.2	21.8	60.8	13.2
Slaughtering and packing	1.5	3.9	91.3	3.3
Smelting and refining, copper	0.7	3.8	94.4	1.1
Smelting and refining, lead	0.9	3.4	94.8	0.9
Sugar and molasses, not including beet sugar	0.9	2.8	92.6	3.7
Tobacco manufactures	4.6	19.0	48.4	28.0
Woolen, worsted and felt goods and wool hats	2.6	18.7	72.9	5.8
All other industries	6.4	21.1	62.1	10.5

A woolen mill owner and operator furnishes the following table:

Materials	Labor	Expense
Raw stock	Office	Insurance
Soap	Factory	Taxes
Dyes	Overseers	Charity
Wool		Executive salaries
Coal		Depreciation
Wool oil		Repairs
Cotton and shoddy		

Percentages were not given, but the total annual expense, including the three subdivisions above shown, is divided by the number of yards of cloth turned out to determine the cost price per yard.

I am familiar with the actual cost of reducing a ton of garbage by the naphtha process. This, on a percentage basis, is as follows:

	Per cent.		Per cent.
Labor	47.43	Superintendent	3.97
Coal	20.81	Taxes	0.45
Pressing	12.37	Interest	0.28
Filter cloth	2.89	Office	0.24
Gasoline, oil and light	8.00	Commission and analyses	0.74
Freight	1.77		

Labor is shown to cost an excessive amount. The gasoline item needs investigation.

The following elements compose the cost of a small copper instrument:

	Per cent.		Per cent.
Labor	61.62	Paint	0.22
Raw materials	27.41	Screws	0.22
Burner	6.03	Lacquer	0.55
Hanger	1.31	Bolts	0.33
Polishing	1.64	Solder	0.11
Support	0.54		

Obviously the labor cost of the instrument is excessive.

The official having charge of the cost department should ascertain at fixed intervals, by inventory and from records, the exact unit cost of any or all articles produced. This information should be made a part of a blue-print chart, carrying at the left a list of the items composing the record and a continuous line, showing the fluctuations in the cost of each, from month to month. If any one of these lines arise from causes beyond the control of the management, others must fall if the price of the finished article is to be maintained. Heating and lighting will fluctuate with seasonal changes; interest and depreciation, charity and office will remain practically horizontal. Unless the industry controls its own raw materials these usually increase in price; labor of all kinds increases; power is more expensive because coal is higher in price and water power has, in many plants, been replaced by steam. There is a very gradual rise in transportation costs and in supplies; taxes and insurance are constantly increasing everywhere.

With such records available, the operating manager is able to determine where efficiency methods could be applied to advantage.

In a former paper before the Institute, I have discussed "Power" from a percentage basis. Since that time, the use of electricity has become quite general and the horse-power year cost has been considerably lowered in a large number of plants.

STOCK AND SUPPLIES.

The raw materials needed in operations of the manufacturer are usually closely bought and economically handled. I have found this particularly true in woolen, cotton and paper mills.

Every successful enterprise requiring raw stock must include an expert buyer of large experience, whose business it is to make a study of market conditions and fluctuations. Ten years ago, much more practical experience was required to fill such a position than at present. This has been brought about by the general introduction and use of specifications. One by one, natural products have been standardized; coal, wool, cotton, ores, oils, paper stock, iron and steel and natural earths; these are a few of the hundreds of raw materials used by manufacturers. Physical and chemical standards have been set to replace the guess and estimation methods that came from experience and that are often wide of the truth. A relatively inexpensive man who has a testing laboratory at his disposal can determine the actual value of raw stock much more accurately than some high-priced man can guess at it. Two items on our cost sheet can be turned downward and kept there at relatively small expense.

Unless the specification idea is carried throughout the mill to include the finished product, the work is incomplete, for the adoption of such a system invariably improves the quality of the goods turned out. For example, every piece of wood, of composition and metal that goes into an automobile or locomotive should be of the best quality, proved to be so by actual experiment. This rule holds for all products.

One of the weakest points in the personnel of the mill organization to-day is the purchasing department. I refer more particularly to those in charge of the purchase of the supplies. This important branch of the business is often left to incompetent clerks, who antagonize salesmen generally and who buy from men from whom they get the greatest possible return, gifts, dinners, an occasional trip, or even money. Honest traveling men avoid such purchasing agents, to the permanent loss of the business.

SUPPLIES.

Every manufacturer uses mixtures and compounds, of the exact nature of which he has no knowledge; oils, dyes, fillers, adhesives, cleaning agents, waxes and polishes, powders and salts. In some instances, such materials have a total cost of $2,000 per month. Many simple substances are sold in large quantities, at inflated prices. For one concern, I was able to lower the cost of a special substance bought for $50 a ton by substituting the same material from another source at $15 per ton. Good business requires a knowledge of supplies and their component parts, for the purpose of keeping the cost down, for the protection of workmen, and to guard against fire.

No feature of factory economy should be as closely watched as the storeroom. A storekeeper should be in charge every moment of the working day, and should be held responsible for all stock handled, distributing this over a counter only, and never allowing workmen to come behind this. All orders should be signed by proper authority and a carbon copy of each transaction kept. Tools, in particular, and all stock that can be used about home, barn or garden will mysteriously leave the plant, a few cents worth at a time, if a way is found to handle the matter with an easy conscience.

SUMMARY.

In the foregoing paper, I have attempted to point out to you certain methods that can be adopted in the conduct of any manufacturing business. The days of large profits, cheap raw materials and labor have gone for good. With increasing prices and competition, all executives must be economists as well. Efficiency, in its broadest sense, should include promotion, capitalization, location, organization, equipment and operation. Great stress has been laid on the efficiency of labor to the exclusion of matters of equal or greater moment. An exact knowledge of unit costs will reveal the weak points in any plant. The so-called efficiency engineer who spends three or four days in a concern and antagonizes everyone from the bosses to the office boy, can accomplish little good. Weeks and months of study are required to get at the details of the business; to make improvements is a still greater task. The good-will of the employees must be gained and kept to make any progress in economy studies. Discussion and argument naturally follow any change in policy. The man who makes the change should be there to defend himself and drive home his viewpoint.

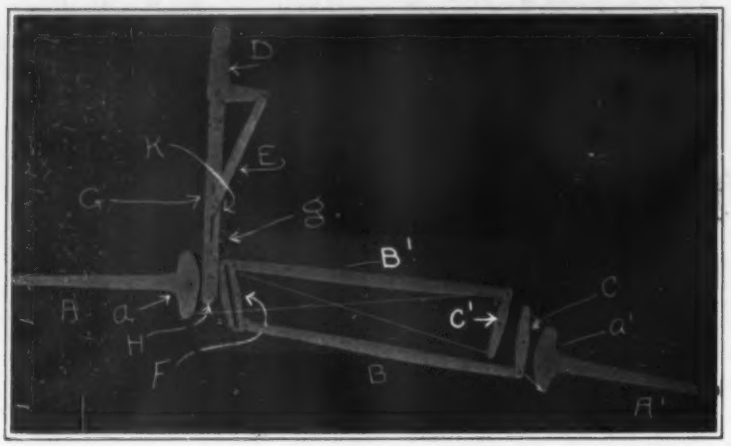


Fig. 1.—Two-rudder System of Control. Cardboard Model Taken Apart to Show Details.

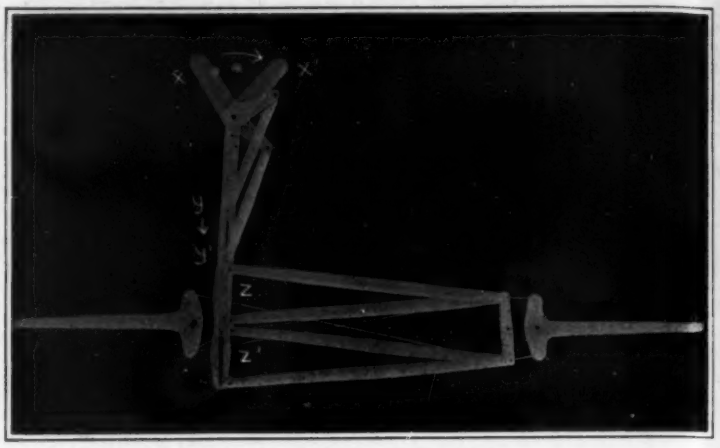


Fig. 2.—Composite Photograph Showing Bell-crank in Its Two Extreme Positions.

The Two-Rudder Control System for Aeroplanes

Description of a Novel System of Aeroplane Control Dispensing With a Vertical Rudder

By Philip Wakeman Wilcox

In designing an aeroplane, the most natural inclination is to follow the lines of the three-rudder class. That is to say, we design the aeroplane with a horizontal rudder to guide the machine up and down, two ailerons or some similar device on either side of the machine to maintain lateral stability, and a vertical rudder to guide the aeroplane in its course in a horizontal direction. The application of a vertical rudder follows naturally from the practice of placing such devices on boats and dirigible balloons, in which cases it is probably the simplest and the best means of guiding the craft horizontally; but as we advance in the art of aviation and strive to approach nearer to perfection, the question arises as to whether this is really a necessary, or an unnecessary adjunct, and if unnecessary, how we are going to discard it profitably, and at the same time obtain the same results that we would have if this rudder were still a part of the machine.

This discussion would lead us to investigate what an aeroplane really is, what is acted upon, and finally, how the desired results are obtained.

Primarily, an aeroplane in flight is a vehicle so supported by the air, that it is affected in some manner by every external force. The horizontal thrust of the propeller forces the aeroplane through the air in a horizontal plane, and if the vertical component of the reaction of the air under the planes is greater than the force of gravity, the machine must of necessity rise and continue rising until the forces are again equalized, in which case the machine travels in a horizontal direction with both of these forces equalized.

Under ideal conditions the aeroplane will continue indefinitely in that state, provided, of course, the pull of the propeller and the weight of the machine remain constant. The aeroplane will not only fly at a constant level, but it will continue flying in a straight line and will maintain equilibrium both laterally and longitudinally, if all forces remain the same.

In other words, we have a condition in which all of the forces are equalized except the pull of the propeller which drags the aeroplane along. Now let any other external force act upon the machine, or let some of the other forces become unequal, and immediately we have another motion to contend with in the direction of the greater force. The most common illustration of this is the inequality of the upward forces or lifts on each side of the aeroplane, causing lateral instability. No matter how slight this difference may be, its effect will be invariably apparent. The slight variations, however, can usually be automatically corrected by setting the wings at a dihedral angle, in which case the sinking side acquires a greater projected horizontal area and has a slightly greater lift, while the projected area of the high side becomes less, and consequently the lift on that side diminishes, the combined effect tending to check this lateral instability or equalize the upward forces on either side of the machine.

When the aeroplane encounters a gust of wind, its inertia will force it momentarily to continue with its original velocity with respect to the ground, so that its velocity with respect to the air is accordingly increased, in which case the lift upward of the planes will be also increased (the lift varying approximately as the square of the velocity of the air under the planes). To counteract the tendency of the machine to rise, it is necessary either to decrease the pull of the propeller or decrease the angle of inclination of the planes by tilting the whole machine down. When the gust of air is in the opposite direction, the machine will necessarily descend and the reverse operation must be resorted to.

The horizontal forces must next be taken into consideration. These are made up of drift, skin friction, and head resistance. The drift is the horizontal component of the reaction of the air under the planes and other lifting surfaces.

If we are flying through absolutely calm air, and our head resistances on either side of the machine and the drift of the planes are exactly equal, we can resolve all the horizontal forces into two unequal forces, i. e., the pull of the propeller on the one hand, and the drift, head resistances, and skin friction of the entire aeroplane on the other.

If, however, these forces on either side of the aeroplane are not equal, there will be rotation of the entire machine about a vertical axis toward the side of the greater resistance. This resistance may be any one of the three resistances or a combination of them. If the difference of resistance be made up of head resistances or skin friction or both, the tendency to turn will be a constant factor, the amount depending of course upon the velocity of the machine.

If the variation be due to an unequal drift, which will usually be the case, it may be due to one of two causes. The angle of the planes may not be fixed right to begin with, owing to careless wiring and tuning up of the planes, in which case the difference of resistances is a constant factor as in the previous case, or the drift may be increased on one side or the other through the operation of ailerons or other devices employed to maintain the lateral balance of the aeroplane, such as warping the wings.

There are numerous air disturbances which may cause an inequality of the horizontal forces, and so we must find some means of introducing another external force which can be varied so as to equalize the forces on either side of the plane again, in order to keep flying in our straight course.

The most common device is the vertical rudder, which can be manipulated so as to produce a moment about the vertical axis in either direction, and which can be utilized either for changing the direction of the machine in a horizontal plane for steering to right or left or for counteracting the unequal forces which are tending to cause rotation and thus keep the aeroplane in its predetermined course.

Thus we find a continual battle of the forces, to tilt the machine up or down, to right or left or to overthrow its balance laterally.

If we are to regard nature as the goal toward which we are approaching in our striving for perfection, does it not seem as if the vertical rudder were showing a disregard for her teachings? There is no parallel in nature to the vertical rudder, which we deem as indispensible in aviation.

The birds have nothing corresponding to a vertical rudder, whose primary function is to steer to right or left. Even the fish do not depend upon their tails for steering, using their fins instead, while the tail acts as a propeller. In the case of the flying birds, the wings are utilized to sustain the bird in flight, for balancing it laterally, and for steering horizontally, although it is a fact that the tail and body are used to assist. In watching a bird in flight closely, it will be noticed that the wings are always under a more or less nervous motion.

When the bird desires to change its course, it does two things. First, it banks by means of its wings, and then by the increased forward resistances of either wing tip, it turns. It would thus seem as if there were a distinct relation between steering and banking. An exception to this rule must be made in the case of birds becoming tired, in which case it might be said they become careless and neglect to bank as much as would otherwise be the case. This was proved by an experiment in which a number of pigeons were sent up on a very windy day, and whenever they attempted to alight were frightened so as to force them to remain in the air. All the time an observer was watching them closely with a field-glass, and as the birds became exhausted, it was noticed that the banking which accompanied the turning became proportionately less. The one is never seen without the other, and the amount of banking is a function of the sharpness of the turn and the velocity of flight. The bird has in a sense, the key to the entire situation in its wing tips. In other words, the bird may be classed as a heavier-than-air vehicle of the two rudder system.

The question now arises, as to how we may accomplish this result, and the answer is in the mechanism which is illustrated herewith. In this device we are able to equalize the drift of the ailerons so that there may be no tendency for the machine to turn about a vertical axis when the ailerons are put into operation, by reason of one aileron causing a greater resistance than the others.

We may also regulate the resistances offered by the ailerons when in use by a motion of the wrist so that the difference of resistance of either aileron may be controlled at will. If we wish to turn to the right, we move the wrist in that direction, and proceed to bank the machine by pushing the aileron lever back or forth as the case may require. Now this lever movement causes one aileron to move more than the other so that there is a decided additional resistance on the side of that aileron having the greater angle, thus tending to turn the machine around that end. Anybody who has ever operated an aeroplane with the Farman type of ailerons knows this to be a fact. The writer knows it to his sorrow as his unfamiliarity with that type caused a very serious accident.

In negotiating a turn the operation would be first to move the wrist lever; second, to operate the lever controlling the aileron, causing the machine to turn and bank simultaneously; third, to bring the machine back to a level position again. This can be done by operating one aileron more than the other or equally. In the first case the unequal resistance of the two ailerons would cause the machine to continue turning. In the second case the machine would go in a straight line while recovering.

The model shown in the accompanying illustration was made of pasteboard, and the photographs, with the exception of Fig. 1, are what might be called com-

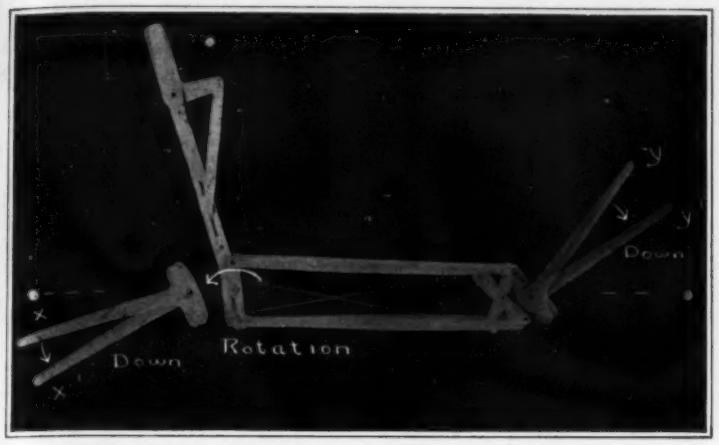


Fig. 3.—This Shows the Bell-crank in the Central Position, but Lever *G* Moved to Extreme Position.

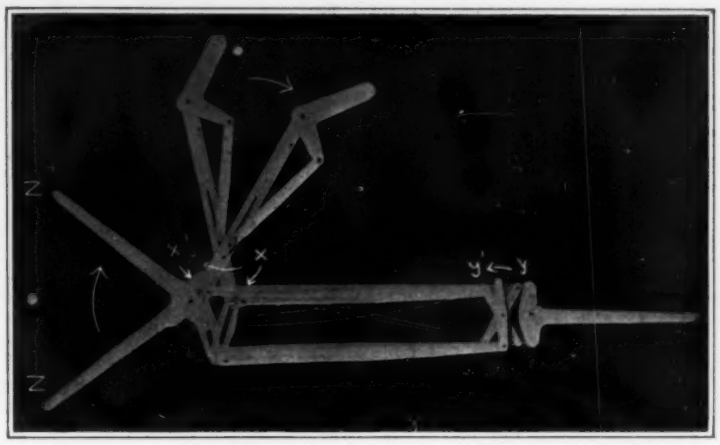


Fig. 4.—Position for Making Horizontal Turn: Bell-crank in Extreme Position, Lever *G* Moved as Shown by Arrow.

posite photographs, because they consist of a number of exposures on the same film in order to show the effect of moving any particular part of the mechanism.

In Fig. 1 the model is shown taken apart in order to facilitate the explanation of the parts. *A* and A^1 represent the ailerons hinged at *a* and a^1, which, in a regular system, would be the front edges, so that the rest of the aileron would trail in the air current passing above and below them. *G* is a lever pivoted at *g*, a fixed point of the aeroplane. *D* is the hand bell crank hinged at the top of the lever *G*. *E* is a connecting rod to *K*, which is so arranged as to slide up and down the lever *G*. *F* is a slotted link, the slot of which engages a pin fixed at the end of the lever *G* at *H* and so connected to *F* that as *F* is moved up or down the lever *G*, the link is likewise actuated so that the pin *H* engages the link *F* in different positions of the slot from one extremity to the other.

The extremities of the link *F* have attached to them; rods *B* and B^1 which are also connected at their other extremities to small rocker arms *C* and C^1, both of which are pivoted at their central points to a fixed point of the aeroplane, the one pivot serving for both rocker arms. The rocker arm C^1 is attached to the aileron *A* by crossed wires running from the extremities of the rocker arm to the extremities of the rocker arm attachment of the aileron *A*, so that when the rocker arm C^1 is rotated in a clockwise direction the aileron *A* is rotated in a counter clockwise direction.

The rocker arm *C* is connected to the rocker arm attachment of the aileron A^1 by direct wires, so that the rotation of both is in the same direction.

Fig. 2 shows the bell crank *D* moved from one extreme to the other; also the link *F* moved from one extreme to the other. This, it will be noticed, does not affect in any way the original position of the ailerons. That is to say, with a mechanism similar to this on an actual flying machine while in flight, the bell crank could be moved from one extreme to the other without in any way disturbing the lateral balance of the machine through any action of the ailerons.

Fig. 3 shows the mechanism with the bell crank in the central or normal position, but the lever *G* moved from the central position to one extreme. The ailerons are shown in two positions. The first is the case in which one aileron *X* is at an angle of approximately 15 degrees below the horizontal position of the aeroplane (shown by the white dot) and the other *y* is about 45 degrees above the horizontal. This is, of course, a very exaggerated position, and one which would never occur in actual practice, but it illustrates the point, and so it is assumed that a condition arose in which, in order to equalize the forward resistance, it was necessary to have the ailerons in that position, or the aileron *x* on the left at an angle only one third that of the angle of the aileron *y* on the right.

I have assumed the flying angle of the aeroplane to be about 3 degrees when flying at a constant level. That is to say, the chord of the plane is 3 degrees to the line of the current of air through which it passes. If we are making a very steep volplane, the angle between the chord of the planes and the air current will change to a lesser angle, owing to the increased velocity of the machine, and the reverse will be true in ascending. Now if we had a machine of the ordinary type with the ailerons set so that they would have an angle equal to zero when the machine was flying at a constant speed and level, then this condition would change if the machine should ascend or descend. Thus the positive angle of the aileron on one side would be of a different amount than the negative angle of that on the other side, taking the horizontal position of the machine as a reference. By horizontal position of the machine I mean the line of the air current as it passes under and above the aeroplane when flying at a constant level.

Suppose that suddenly the conditions change so that we must have equal angles of the ailerons on either side of the aeroplane with reference to the line of flight. In other words *x* must increase from 15 degrees to 30 degrees negative, and *y* must decrease from 45 degrees to 30 degrees positive.

Now let us see just what happens during this change. The aileron *A* turns in an anti-clockwise direction, causing the rocker arm C^1 to turn in a clockwise direction. Aileron A^1 turns in a clockwise direction and causes rocker arm *C* to turn in a clockwise direction. The angles turned through by the ailerons in each case are equal, but of opposite direction, while the angles turned through by the rocker arms are also equal, but in the same direction, so that the combined effect on the link *F* is one of rotation about its pivot, but without in any way causing any disturbance of the lever *G*, the entire action being pure rotation and no translation. In other words the ailerons are affected by the lever *G* in such a way that when the lever is actuated from one extreme to the other, the ailerons are rotated in different directions, causing a lifting effect on one side of the aeroplane and a depressing effect on the other; but the relative angles of the two ailerons with respect to the ends of the aeroplane are not in any way controlled by this lever. They are free and are bound to assume angles which will equalize the horizontal pressure on either side of the machine, as they will both move up or down at the same time the same amounts without affecting the controlling lever.

Now take the case in which we wish to turn in a horizontal direction. It has been stated that this can be done by increasing the horizontal resistance of the side toward which we wish to turn. Fig. 4 shows how this may be accomplished. The bell crank is turned to the extreme position so that the link is engaged with the pivot on the extreme end of the lever *G* at its upper extremity. Now as we move the lever *G* from the first position to the second, let us investigate what happens. We will assume that a current of air is passing above and below each aileron tending to hold it in position, so that to move it up or down would require a decided effort. As we move the lever *G*, the extremity connected with the link *F* is almost directly connected with the rod B^1 actuating the rocker arm C^1, so that the lever *G* moves from *X* to X^1; the aileron A^1 is connected by the rod *B* to the other end of the link *F*, and as this is a loose connection there is no force acting on the rod *B*, which would tend to move the aileron A^1 against the forces already acting on it, tending to hold it in position as already stated. So we have the case of being able to move one aileron independently of the other. If we were to move the bell crank to the other extreme, the aileron A^1 would be the one to have all the force exerted upon it and *A* would remain neutral. As we go from one extreme to the other we have the forces varying from the entire force on one aileron to the entire force on the other aileron, and at the central position the forces on the two are equal as we move the lever *G* back and forth.

In flying with this attachment on the ailerons, when we desired to make a turn it would first be necessary to turn the bell crank according to the direction in which we wished to go, and then move the lever *G* in such a position as to bank with the low side toward the direction of turning. In other words, the operation would be exactly similar to the control system already used on some of the very best-built of the aeroplanes of to-day.

In flying straight the ordinary back and forth motion of the lever would control the lateral stability, and as the ailerons are automatically balanced, it would be unnecessary to use any other mechanism or rudder to keep the machine in its predetermined course.

An Ancient City and Its Remarkable Irrigation System

HAMA, the Hamath of the Bible, one of the oldest cities of Syria, is situated in the valley of the Orontes, 110 English miles N. (by E.) of Damascus. It finds a place among the northern boundaries of the Holy Land (Num. xxxiv. 8), and is frequently mentioned in Old Testament history. The city lies in a narrow valley, the pass south of it being probably the "entering in of Hamath" (1 Kings, viii, 65). The Orontes flows winding through it, and is spanned by four bridges. On the southeast the houses rise 150 feet above the river, and there are four other hills, that of the Kalah or castle to the north being 100 feet high. Twenty-four minarets rise from the various mosques. The houses are principally of mud, and the town stands amid poplar gardens with a fertile plain to the west. The castle is ruined, the streets are narrow and dirty, but the bazars are good, and the trade with the Bedawin considerable. The population is stated in official returns to consist of about 39,000 Moslems and 4,000 non-Moslems. The curious Hamath inscriptions first mentioned by Burckhardt have lately attracted much attention. Four stones exist covered with ideographic designs in a character as yet quite unknown. The latest researches of Mr. George Smith, however, indicate that the inscriptions are probably of Hittite origin, and other relics of that once powerful nation resembling the Hamath stones have been discovered farther east.

The Orontes River flows through the city in the form of an S, and upon its banks are four huge water wheels, each bearing a name of its own. They are used for pumping up the water of the Orontes for irrigation purposes, and also for supplying the town.

The wheels are driven by the flow of the river on what is known as the undershot principle; that is to say, the wheel is moved by water passing beneath it. The largest wheel has a diameter of about 70 feet, and the Syrians declare it is the largest in existence. Like the others, it is built of wood, a dark mahogany. The axle is of iron. The creaking of the wheels is incessant day and night. They never stop. In winter and during early spring the flow of the stream is partially blocked to reduce the rapidity of the revolutions, but on no account are the wheels actually stopped.

Placed upon the banks of the stream amid the trees and gardens for which Hama is justly proud, the wheels present a decidedly picturesque effect. They are the favorite rendezvous of the boys of the town. For a few cents some of the more daring will climb up the spokes of the moving wheel to the summit and then jump into the stream below him.

The Origin of the Philistines

THERE is considerable uncertainty regarding the origin of the Philistines, the people from whom Palestine takes its name. There are two favorite hypotheses; according to one the place of origin of this nation is Egypt; the other makes the isle of Crete their original home. The second of these suppositions has received much support by ethnological explorations carried out by an English expedition, which has discovered the ruins of Beth Chemech, a city founded about 1500 B. C. and mentioned in the Bible.—*La Nature.*

The House Fly: How It Spreads Disease*

A Parasitic Fungus Suggested as a Means to Control the Menace

By Edgar Hesse

TEN years ago our ignorance of the biology of that common insect the house-fly was deplorable. A few scientific men, suspecting the insect of carrying harmful bacteria, undertook research work, which has resulted in not only enriching our knowledge of the life-history and anatomy of the house-fly, but proving up to the hilt that the filthy habits of the fly are one of the means of spreading many infectious diseases.

In 1908 the Right Hon. John Burns, M.P., authorized the Local Government Board to make exhaustive inquiries into this important subject, and a number of Blue Books have been issued containing the reports of experiments conducted with such minute care that one is forced to accept the results as conclusive evidence of the guilt of the house-fly.

The house-fly is included in a large family of flies known as the Diptera, or two-winged flies. The hind pair of wings are rudimentary, and are represented by a pair of appendages shaped somewhat like drumsticks. These are known as balancers, and are believed by some to be of use to the insect in maintaining its equilibrium.

The muscles used in flight occupy the larger portion of the thorax. Great buoyancy is given to the insect by numerous air-sacs and a tracheal system which permeates all the tissues of the body. These air-tubes, or trachea, take the place, in insects, of blood-vessels and capillaries in higher animals, and in an active insect such as the house-fly we find a rich tracheal system. The two large compound eyes, each of which is composed of about 4,000 faceted individual eyes, produce a single blurred image, not thousands of individual images. In the space between the compound eyes are three simple eyes, arranged in a triangle. The width of this space on the top of the head enables one to identify the sex without dissection. In the male, the eyes are separated by about one-fifth of the breadth of the head. In the female, the space is wider, or about one-third of the breadth of the head. The proboscis, or what is popularly known as the tongue, of the fly is a most wonderful organ. It takes the place of the jaws of other insects who chew their food, or in blood-sucking insects, who pierce the skin of their victims. The house-fly cannot bite, and can only take its food in a liquid form. When the fly alights on food, it protrudes its proboscis by a combined action of the air-sacs in the head and the blood. The blood in the head is not confined to blood-vessels, but occupies the cavity of the head not taken up by the capacious air-sacs, brain, and other organs. Dr. Hewitt asserts that an expansion of the air-sacs in the head forces the blood into the proboscis, the result being something similar to blowing air into the drawn-in finger of a glove. The oral lobes, when not in use, close like the valves of a mussel, and the surface of each is provided with a number of sense-organs and long hairs, which are also sensory in character. These organs enable the fly to taste and smell. The lobes of the proboscis are provided with a number of channels, which direct the food by suction exerted by a powerful muscular pump—the pharyngeal pump—upward to the œsophagus. Two pairs of salivary glands open into the proboscis. The alimentary canal, after passing into the thorax, opens into the proventriculus, but before doing so gives off a dust on the under-side, which leads into the crop, situated at the front end of the abdomen, and on the ventral side. We have now arrived at a portion of the fly's anatomy which is most important, and which will demonstrate the capability of the insect in distributing bacteria. The proventriculus is a valvular organ under the control of the insect. If the fly is hungry and the crop is empty, the proventriculus remains closed. The food then passes into the crop. If the food is plentiful, and the fly is not disturbed, after the crop is filled the proventriculus opens, and the food then is passed into the ventriculus, or chyle stomach. The crop therefore serves as a store for a reserve food supply, and it has been proved by experiments that food material remains in the crop of a fly several days if food is plentiful. It has also been proved by experiment that the fly has a habit of regurgitating food from its crop down through its proboscis, mixing it with saliva for the purpose of moistening food material on which it desires to feed, reabsorbing the same several times. These vomit-spots are to be noticed on window-panes, and, being of a lighter color, can be distinguished from the fecal deposits, which are usually brown.

It does not require a very vivid imagination to picture what happens when a fly, glutted with a meal from the sputum of a tuberculous patient in the district, flits gaily on to the sugar on your tea-table, from the dustbin, or more indescribable filth! To taste your sugar, your cake, etc., he must vomit on it, and not once, but several times, reabsorbing the fluid, and wandering to fresh spots, leaving traces of the contents of his contaminated crop. The glutinous pads on his feet are contaminated by the substance from which he has just flown. The bristles of his legs and body all help to distribute some undesirable filth, with probably pathogenic bacteria included therein.

The breeding places of the house-fly are manure heaps, rubbish shoots, any decaying vegetable matter, mixed at times with animal matter. Excremental substances are most favored. Temperature and moisture are the governing factors. The higher the temperature, the quicker the eggs will hatch and the larvæ will feed. The female deposits from 100 to 150 eggs at a time, and five or six, and possibly more, batches of eggs can be deposited during its short life. With a high temperature the egg will hatch in from eight to twenty-four hours after being deposited. The larvæ may become full-grown in five days, and hatch from the chrysalis in three more days. The insect hatches from the chrysalis full-grown. It has been a popular error that the smaller flies seen about the house in the spring are young ones. They are the lesser house-fly, *Fannia canicularis*, and appear before the greater house-fly, *Musca domestica*; but their habits are similar. It has been found that in warm cellars and kitchens flies will deposit eggs, and the larvæ will feed and develop during the winter months.

Before touching on the diseases known to be spread by flies, I should like to quote Sir Ray Lankester, who has stated that "Within the past few years, the knowledge of the causes of disease has become so far advanced that it is a matter of practical certainty that, by the unstinted application of known methods of investigation and consequent controlling action, all epidemic diseases could be abolished within a period of so short as fifty years." I presume he had taken the menace of the house-fly into consideration, and sincerely hope this forecast will prove true. The diseases known to have been spread by the agency of the fly are typhoid fever, summer diarrhœa (especially in infants), enteric fever, tuberculosis, cholera, anthrax, ophthalmia, myasis of the intestinal and urinary tracts, and the spread of parasitic worms.

The question of a pure milk supply has been before the public of late; but I think that whatever steps are taken by the producer and retailer of milk will be nullified by the house-fly, if he is permitted to still invade the homes of the consumer, as at present. Milk has a great attraction for the fly, and, unfortunately, is a food which is easily infected by him, and the danger to infants and invalids is thereby quadrupled. In regard to preventive measures, very little has really been accomplished. The early removal of horsedung from the centers of large towns has relieved those towns at the expense of the suburbs and country districts, where the manure and rubbish is dumped. From America comes a suggestion to sprinkle chloride of lime on the manure to prevent the flies laying their eggs. I am afraid that the quantity of chloride of lime required to effectively keep away the flies would be more than sufficient to render the dung quite unfit for manure for agricultural purposes. Improved sanitary methods, and the careful screening of food, the destruction of rubbish by burning, seem to be the measures recommended by most authorities. The parasitic fungus of the house-fly, *Empusa Muscæ*, has been mentioned in the Local Government Board's reports as a possible factor in the control of the house-fly. Many attempts have been made since its discovery in 1885 by Varley to cultivate it; but without success, until last summer, when I obtained an artificial culture, and used the spores experimentally, killing a number of flies both in confinement and in open rooms. The method adopted has simplicity to recommend it. The spores were used mixed with a syrup composed of sugar and water; paper was coated with the mixture, the sugar acting as the bait to attract the fly. The fly absorbed the spores in the act of sucking the sugar from the paper, thus inoculating himself! The filthy habit of the fly of vomiting on dry food material assisted in this. The peculiar crop of the insect also aided in his destruction. If the crop is nearly empty, the spore is deposited in it with the food material absorbed, and will germinate there. When this takes place, nothing will save that fly. If it happens that the crop be full, then the spores will pass into the proventriculus, and through the digestive system too quickly for germination to take place, and that fly escapes for a time. I cannot definitely state the time required for the fungus to kill the fly. In my experimental cage, the first deaths occurred in about 12 days after placing the flies in the cage. In using the fungus-spore papers in the open rooms, the migratory habits of the flies prevented a proper estimate of the percentage of deaths. It was, however, demonstrated that the number of flies which succumbed to the fungus was very much greater and earlier than usual under normal conditions. If this is the result of a small experiment, greater results may be expected if the spores are used by the public in large quantities.

The spores of this fungus are not harmful to any life except that of the house-fly. The bluebottle flies are unaffected by this fungus. I have experimented with varieties, but cannot state that in any specimen could I ascribe the death to the fungus. The bluebottle fly is a scavenger, and, compared to the house-fly, is a friend, and he does not frequent our dwellings to the same extent as the house-fly. The flies killed by the artificially-cultivated spores were the greater house-fly, *Musca domestica*, the lesser house-fly, *Fannia canicularis*, and the stable-fly. The last growth of the fungus, which protrudes from the proboscis and feet, fixes the insect to the spot where it dies in a most lifelike position. After death, the spores are thrown off from the short hypha with considerable force, forming a halo which can be seen to advantage if the fly dies on a window-pane.

*A paper read before the "Lionel Jacobs" Physical and Chemical Society in the Museum of the Working Men's College, Crowndale-road, Camden Town, N. W., on February 22d, 1913.

Dana's Proof of Darwin's Theory of Coral Reefs*

Barrier Reefs Formed by Subsidence

By W. M. Davis

JAMES DWIGHT DANA, born four years to a day after Darwin, on February 12th, 1813, naturalist of the United States Exploring Expedition under Wilkes from 1838 to 1842, and afterwards until his death in 1895 professor of geology at Yale University, was for more than half a century a leading figure among American men of science. On the hundredth anniversary of his birth it is fitting to direct attention to the independent proof that he found many years ago for Darwin's theory of coral reefs, a proof that has long been overlooked, although it supplies the most important confirmation for the theory of subsidence that has ever been brought forward.

Darwin most ingeniously invented his theory of subsidence while he was in South America, before he had seen a true coral reef; he had afterwards only to test the theory by comparing its consequences with the facts that he observed during the voyage of the "Beagle" across the Pacific and Indian Oceans, and with the records of other explorers which he studied after his

*Reproduced from *Nature*.

return home. The theory bore the test admirably; it was universally regarded as "true" for a generation, although apart from certain correlations of coral reefs with areas of recent uplift and with active and extinct volcanoes, which appear to be less assured now than seventy years ago, the theory of subsidence did not gain that increased probability of correctness which comes to a theory from the capacity to explain facts that were unknown or unnoticed when the theory was invented.

During the last thirty years several new theories of coral reefs have been introduced, and Darwin's theory has been more or less discredited in the minds of some investigators. Murray re-introduced what may be called the theory of outward growth, which Darwin had considered and adopted for certain special cases in association with subsidence; but in its new form subsidence was excluded from this theory, and two provisos were added as to the organic upbuilding of submarine banks until they reach the moderate depth at which they may serve as foundations for atolls, and as to the production of lagoons by the removal of the inner part of reefs by solution (Proc. Roy. Soc., Edin., ix., 1880, 505-518). Agassiz, in his world-wide explorations of coral reefs, emphasized the possible complications in their history; he pointed out the frequent occurrence of uplifted "coralliferous limestones," which might be worn down and dissolved away while fringing reefs grew around them, thus producing barrier reefs and atolls in association with elevation instead of subsidence. At the same time he reintroduced the idea —which Darwin had rejected on good grounds—that reefs could grow on the outer margin of platforms cut by the waves around volcanic islands, thus producing barrier reefs without subsidence, elevation, or solution (Bull. Mus. Comp. Zool., xxxiii., 1899; Mem. Mus. Comp. Zool., xxviii., 1903). Wharton went still farther in suggesting that a volcanic island might be worn down to a depth of twenty or twenty-five fathoms by marine agencies, thereby producing a flat submarine bank on which an atoll could afterwards grow up; thus accounting for atolls as Agassiz had for barrier reefs, without subsidence, elevation, or solution.

The possibility of producing barrier reefs and atolls by the wearing down of uplifted "coralliferous limestones," as suggested by Agassiz, may be regarded as a modification of any theory that will explain barrier reefs and atolls before the uplifts occurred. Darwin recognized at least one instance of wearing down an uplifted reef ("Coral Reefs," 1842, p. 55), and would certainly have welcomed the larger application of this process, had he known the results of modern exploration.

The formation of atolls by up-growth from submarine banks of proper depth is eminently possible, if the banks can be provided in sufficient number, but possibility is not proof. When subsidence is demonstrated as having taken part in the production of barrier reefs, as will be shown below, its exclusion from this theory of atolls is unreasonable.

The development of a foundation of atolls by the marine truncation of a volcanic island, as indicated by Wharton, is eminently possible, provided that floating coral larvæ do not establish themselves upon it until truncation is complete; but the ordinary relation of fringing and barrier reefs to their central islands shows that this proviso is inadmissible. The formation of a fringing reef will be begun as soon as a narrow platform is abraded, and such a reef once established, further truncation of the island by wave work is practically stopped. Moreover, the Alexa and other submarine banks described by Wharton can be explained by regarding them as submerged atolls quite as well as by regarding them as truncated volcanic islands; hence this theory is not satisfactory.

The formation of veneering barrier reefs on the outer margin of sea-cut platforms around still-standing islands, an old idea (see footnote in Darwin's "Coral Reefs," 1842, p. 49) recently given prominence by Agassiz, is open to the same difficulty that is fatal to Wharton's theory of truncation. However, if a barrier reef were ever formed in this manner, the central island should rise from the cut-back shore line in a wall of steep cliffs, as Darwin clearly stated, and the broader the platform, the simpler the outline of the cliff-walled island should become. It may be confidently asserted that the central islands of barrier reefs do not possess these significant features; hence there is no more reason for accepting this theory to-day than when Darwin rejected it.

The theory of outward growth and solution, advocated by Murray for the production of barrier reefs around volcanic islands, without subsidence, or even in areas of slow elevation, involves several consequences which, when compared with the facts, contradict its verity; for during the slow outward growth of the reef around a still-standing island, the streams from the mountainous interior must form deltas in the shallow water at their mouths, and by the time the reef has grown far enough outward to be called a barrier, the delta plains must become more or less confluent laterally, thus forming a low alluvial plain around the original island, as Darwin clearly saw ("Coral Reefs," 1842, pp. 128-130). When such lowlands occur, they indicate a still-stand of the island; but their prevailing absence suffices to exclude the general application of the postulated stillstand.

It would thus appear that the theories of outward growth and solution for the production of barrier reefs, of marine truncation for the production of atolls, and of coral veneers on the margin of sea-cut platforms for the origin of barrier reefs, all fail to satisfy the requirements of observation, when they are tested by certain consequences that have not been explicitly stated by their inventors. It remains to be seen whether Darwin's theory of subsidence suffers the same fate when tested in the same manner.

The accompanying diagram clearly exhibits three stages in the subsidence of a dissected volcanic island; the first stage shows a fringing reef, the second a barrier reef, the third an atoll, as indicated by Darwin's original figures, which are here reproduced in substance on the front face of each block. But the surface of the second block shows a feature which Darwin did not notice, although it is quite as essential a consequence of his theory as any other. This is the invasion of the previously eroded valleys of the subsiding island by the sea, so that the relatively simple shore line of the first stage is in the second stage transformed into an embayed shore line, possessing several of "those deep arms of the sea . . . which," as Darwin said, "penetrate nearly to the heart of some encircled islands" ("Coral Reefs," 1842, p. 49). So long as subsidence continues the bays cannot be filled with deltas and the ridges cannot be cut back in cliffs. Darwin recognized that the central island must diminish in size as it subsides, but he did not also perceive the necessary modification of its outline.

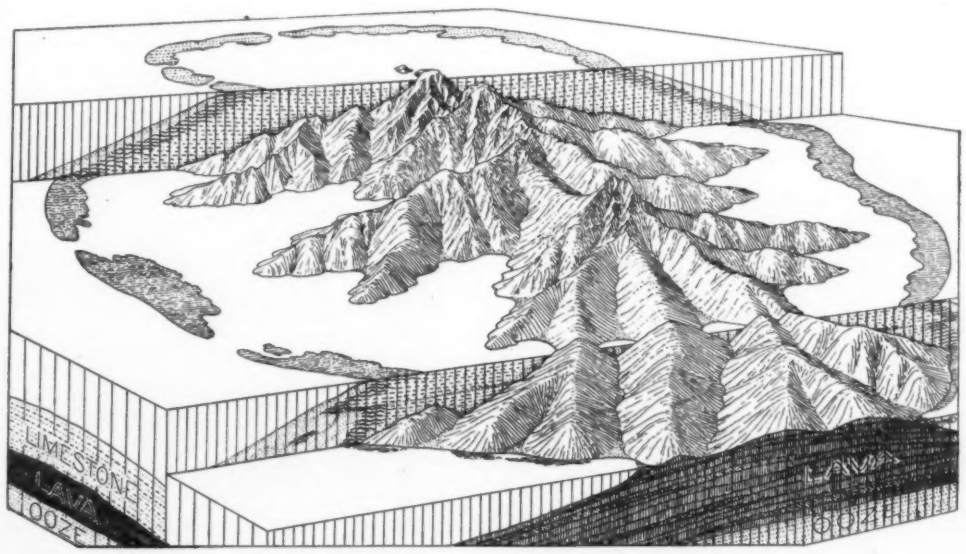
It requires but a brief examination of large-scale charts of the Pacific island-groups to discover that the central islands of barrier reefs are repeatedly characterized by an embayed shore line, that the bays are not filled with delta-plains, and that the ridge ends are not truncated in cliffs. Kandavu and Mbengha in the Fiji group (Admiralty chart 167), the western members of the Society group (chart 1060), and especially Bora Bora (1428), Gambier Island (1112), a western member of the Paumotus, and Rossel Island (1473), in the Louisiade archipelago of British New Guinea, may be instanced among many others as affording good illustration of at least some of these features, particularly of embayed shore lines.

In view of the remarkable accordance that is thus found between the inferred consequences of the theory of subsidence and the observed features of central islands of barrier reefs, and in memory of the failure of corresponding consequences of other theories to match the facts, an open-minded inquirer cannot hesitate long in making choice among the several explanations that have been suggested for barrier reefs, and with them, of atolls.

Dana first learned of Darwin's theory when the Wilkes expedition reached Sydney near the end of 1839. Several months earlier, during "the ascent of Mt. Aorai on Tahiti, in September of 1839," he had conceived the production of an embayed shore line as a necessary result of the subsidence of a dissected land mass. Let it be noted in passing that he was the first clearly to announce this important principle, which then had no place in geology or geography, although it is hinted at in De la Beche's "Researches in Theoretical Geology" (London, 1834, p. 193). In Dana's first report he says, when following Darwin in explaining barrier reefs and atolls by subsidence:—"The very features of the land, the deep indentations, are sufficient evidence of subsidence to one who has studied the character of the Pacific islands" ("Geology," U. S. Expl. Exped., 1849, p. 131); and on a later page a more explicit statement is made under the general heading, "Deep Bay-indentations in Coasts as the Terminations of Valleys":—"In the remarks upon the valleys of the Pacific islands, it has been shown that they were in general formed by the waters of the land, unaided by the sea; that the sea tends only to level off the coast, or give it an even outline. When, therefore, we find the several valleys continued on beneath the sea, and their enclosing ridges standing out in long narrow points, there is reason to suspect that the island has subsided after the formation of the valleys. For such an island as Tahiti could not subside even a few scores of feet without changing the even outline into one of deep coves or bays, the ridges projecting out to sea on every side. . . . The absence of such coves, on the contrary, is evidence that any subsidence which has taken place has been comparatively small in amount" (p. 393).

It is remarkable how rarely the value of this capital point has been recognized. It is referred to in Bonney's appendix to the third edition of Darwin's "Coral Reefs" (London, 1889, pp. 310-311), but without sufficient indication of its value as an independent and therefore important confirmation of Darwin's theory. It is noted by Krämer, who gives it local application in explaining certain bays on the Samoan islands, but without recognizing its value in relation to the theory of subsidence in general ("Bau der Korallenriffe," Leipzig, 1897, p. 24). It is quoted by Gardiner, but without understanding of its importance, for he adds: "Such evidence when applied to volcanic islands is, I submit, of very doubtful value" (Proc. Camb. Phil. Soc., ix., 1898, p. 490). Murray does not refer to it; Agassiz quotes and rejects it in reference to the Marquesas Islands (Mem. Mus. Comp. Zool., xxviii., 1903, p. 5), and does not mention it elsewhere. Singularly enough, Darwin himself refers in the second edition of his book only twice, and then very briefly, to Dana's evidence of subsidence; both references concern the Marquesas Islands ("Coral Reefs," second edition, London, 1874, pp. 163, 201). I have found no other passage in which Darwin says a word upon the subject, although his discussion is otherwise marvellously complete.

Doubtless other earlier writers cited Dana's principle, but it has not yet come to be generally accepted as an essential element in the demonstration that barrier reefs have been formed by subsidence. This is probably because an understanding of the reasonable evolution of coastal forms has not yet taken general possession of the scientific mind, or perhaps because some students of the coral-reef problem still adhere to the obsolete explanation of bays by marine erosion, an explanation that Dana explicitly excluded; can it possibly also be because there is as yet no sufficient understanding of the logical principle that a theory, even if it be well recommended by explaining the things that it was invented to explain, still needs confirmation by independent, unexpected evidence, before it deserves to be accepted as "demonstrated"?



Stages in the Subsidence of a Dissected Volcanic Island.

Pioneers in Telephone Engineering

Experiences With the First Telephones

By Thomas A. Watson

[Before an assembly of the Telephone Pioneers of America, Mr. T. A. Watson gave a most interesting account of his connection with the early development of the telephone. The following transcript of the stenographic report of his address has been revised for publication in the SCIENTIFIC AMERICAN SUPPLEMENT *by the author.—*EDITOR.]

My recollections of Dr. Bell's early telephone experiences are only those of a boy, for I was about twenty years old when I first met Dr. Bell. But they are still very vivid, as boyhood's recollections usually are. Those lectures delivered by Dr. Bell in the spring and early summer of 1877 really had a most important effect upon the present development of the telephone. At that time there was a tremendous need for cash. We had just been bitterly disappointed, we four who composed the telephone business at that time—Mr. Hubbard, Mr. Sanders, Dr. Bell, and a boy by the name of Watson. We had just received a terrible blow: The Western Union Telegraph Company had refused our offer to sell all the Bell patents for $100,000, and we were very much depressed over it. Just about that time Dr. Bell needed money, more, I think, than he ever needed it before in his life. He wanted to get married. The need for money was so great that some of the ladies prominently connected with the original four, insisted that telephones be made and sold, by the thousands—as many as could be put out and as quickly as possible. This would have meant the flooding of the country at that time with very imperfect telephones and also would have blocked the plan of leasing them that has resulted in the present unity and universality of the telephone service.

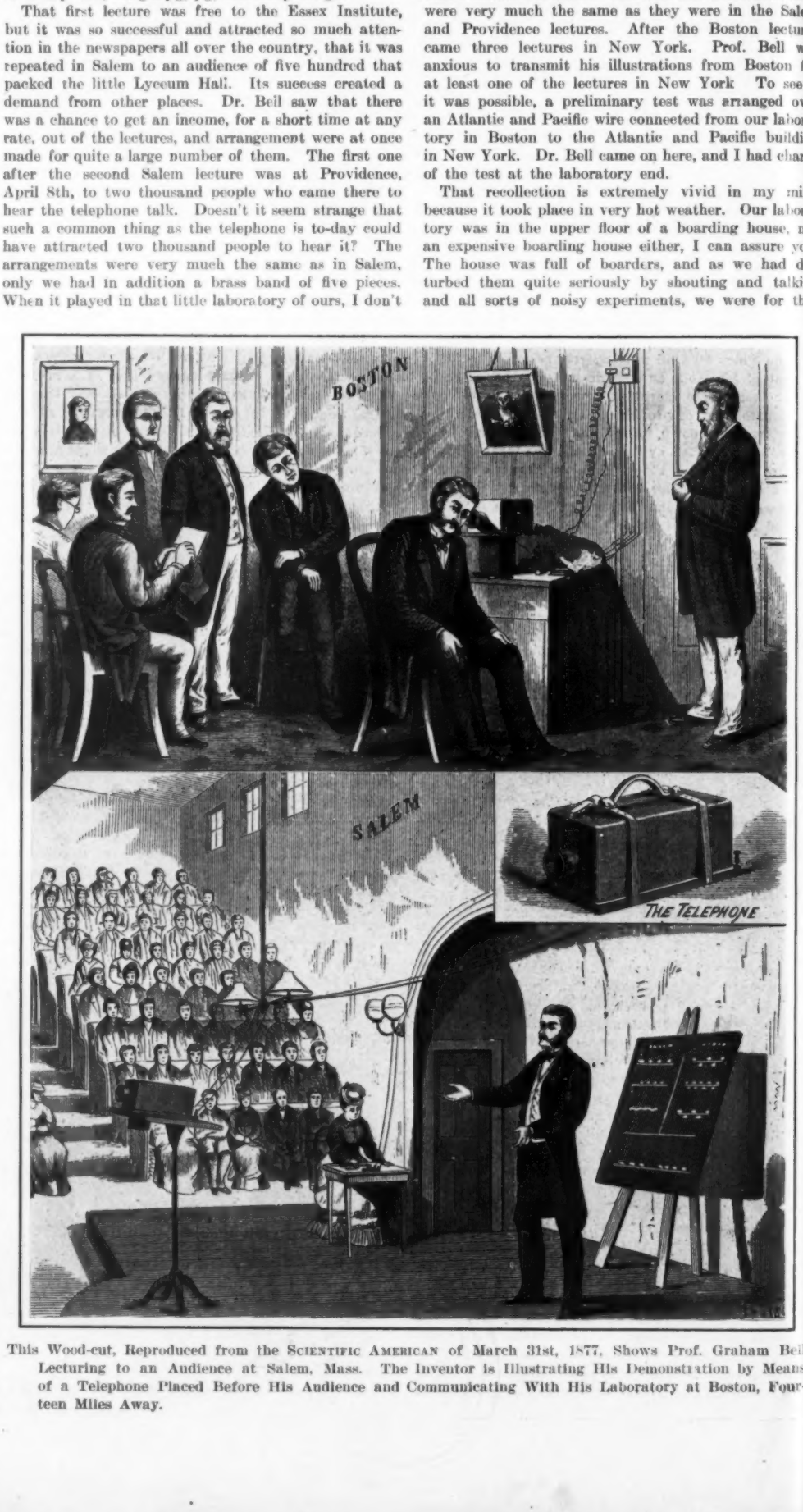
I doubt if that idea had been carried out, of selling these early telephones, whether it would have been possible for the exchange business to have been so thoroughly controlled by the original company as it has been. The lecture course that Dr. Bell gave during the spring and summer did away with the necessity of selling those telephones. We both lived in Salem, a coincidence merely, and in Salem there was a scientific association known as the Essex Institute, an old institution that was interested in botany, bugs, archeology, antiquities, etc. It took an intense interest in Dr. Bell's experiments and invited him in February, 1877, to talk to the members of the society about the telephone and to give them an exhibition of its powers.

This was arranged. We engaged a telegraph wire of the Atlantic and Pacific Telegraph Company to connect our laboratory in Boston at No. 5 Exeter Place with Lyceum Hall. At the Lyceum end there were two or three of those old-fashioned box telephones about fourteen or fifteen inches long and eight inches square with an enormous horseshoe magnet inside of it. At my end I had a cornet player, an organ arranged so that each reed made and broke the circuit each time a key was depressed, as loud a speaking telephone as we had at that time, and, lastly, my own voice to illustrate his lecture course. Dr. Bell discussed his theories and described his experiments, calling on me occasionally, who had to be constantly listening, to illustrate from my end of the wire what he said.

My first illustration was usually with the organ. I would play one or two tunes on that. As that produced a powerful intermittent current it came out very loudly at the receiving telephones at the hall end, even though it was sixteen miles away; then we had some cornet playing, and, although I say it—who should not—the great feature of the evening was the sentences I ejaculated through the instrument. My illustrations were usually about the same thing. They were such sentences as, "How do you do?" uttered in the stentorian voice I had developed at that time. They told me the sound came out at the receiving end, no matter how carefully I articulated it at my end, as something like "hoo, hoo, hoo;" but the rhythm was sufficient to make the audience think they heard the words perfectly; I would shout them other sentences such as "Good evening; it is a pleasant evening." "What do you think of the telephone?" etc. And then came my songs. I couldn't sing, but I had to, for they couldn't get another voice that could make the old box ring as mine did at that time. My repertoire consisted of "Yankee Doodle," "Pull for the Shore" (it was in the Moody and Sankey times), "Hold the Fort," "Auld Lang Syne," and for sentiment, "Do Not Trust Him, Gentle Lady." I remember once, at one of Dr. Bell's lectures, I branched out and added to my repertoire, "Nearer My God To Thee," but I did it but once, for Mrs. Hubbard gave me an awful scolding the next day and I cut that out of my repertoire. After the lectures, the distinguished citizens of the town were invited to speak to Mr. Watson at the other end of the line, and there were reporters to record every word that was said. I remember very vividly how diffident distinguished citizens suddenly became when they were asked to talk through the telephone. One of our leading legal lights of Boston, who certainly should have been able to talk, when asked to speak through the telephone, gasped and all he could think of to say was, "Rig-a-jig, jig, and away we go."

That first lecture was free to the Essex Institute, but it was so successful and attracted so much attention in the newspapers all over the country, that it was repeated in Salem to an audience of five hundred that packed the little Lyceum Hall. Its success created a demand from other places. Dr. Bell saw that there was a chance to get an income, for a short time at any rate, out of the lectures, and arrangement were at once made for quite a large number of them. The first one after the second Salem lecture was at Providence, April 8th, to two thousand people who came there to hear the telephone talk. Doesn't it seem strange that such a common thing as the telephone is to-day could have attracted two thousand people to hear it? The arrangements were very much the same as in Salem, only we had in addition a brass band of five pieces. When it played in that little laboratory of ours, I don't think I ever heard anything quite so loud in my life. It came out at the lecture hall very well, but they all said not nearly as well as Watson's singing. After that, a course of lectures was arranged in Boston. On the request sent to Dr. Bell for that course of lectures, were the names of Oliver Wendell Holmes, Henry W. Longfellow and many other well-known men. The first of these three lectures were illustrated from the laboratory, only about half a mile away from the hall; the second from Somerville; I can't remember where I was stationed for the third lecture, but it was somewhere within ten miles. The talk and the illustrations were very much the same as they were in the Salem and Providence lectures. After the Boston lectures came three lectures in New York. Prof. Bell was anxious to transmit his illustrations from Boston for at least one of the lectures in New York To see if it was possible, a preliminary test was arranged over an Atlantic and Pacific wire connected from our laboratory in Boston to the Atlantic and Pacific building in New York. Dr. Bell came on here, and I had charge of the test at the laboratory end.

That recollection is extremely vivid in my mind because it took place in very hot weather. Our laboratory was in the upper floor of a boarding house, not an expensive boarding house either, I can assure you. The house was full of boarders, and as we had disturbed them quite seriously by shouting and talking and all sorts of noisy experiments, we were for that



This Wood-cut, Reproduced from the SCIENTIFIC AMERICAN of March 31st, 1877, Shows Prof. Graham Bell Lecturing to an Audience at Salem, Mass. The Inventor is Illustrating His Demonstration by Means of a Telephone Placed Before His Audience and Communicating With His Laboratory at Boston, Fourteen Miles Away.

and other good and sufficient reasons not on good terms with the landlady. So I realized that as I had to do the shouting of my life that night, I must muffle the noise. I took the blankets off of my bed and Dr. Bell's, and arranged a sort of a tent over my big telephone with five thicknesses of blanket. When I got the signal from Dr. Bell in New York, that he was ready to hear from me. I crawled in under my blanket tent and for two mortal hours I shouted to him. I needed no Turkish bath that night.

The next morning I asked the landlady rather timidly if I had disturbed the boarders during the night. They hadn't heard a sound. So the experiment was a success, like many others. In connection with one of the New York lectures I got into a very bad scrape. Of course, the singing that would do for Boston wouldn't do for a New York audience. So they engaged a professional singer, a negro, a big man with as superb a baritone voice as I ever heard. The first lecture was illustrated from New Brunswick, on the Pennsylvania Railroad. I went down there in the afternoon and found the negro ready to do his part of the work. I had the rest of my instruments, cornet, organ, etc., and my voice, that was always with me. I rehearsed him a little and told him, when he sang, to put his lips into that mouthpiece as tight as he could and to sing for all he was worth. He didn't like the sound of his own voice when it was so muffled, and I was a little bit anxious about it. But he promised me that he would do just what I wanted him to do that evening. I went to supper and at half past seven I went back there. The young lady operator had invited six or eight of her girl friends to witness that affair at her end of the line. It was clearly my duty to make that negro sing, and so I insisted on his crawling into that mouthpiece when Dr. Bell called for the singing. I held the telephone up to his mouth and chased him half way across the room to keep his mouth close to it, but he backed away and wouldn't sing nearer than an inch. I knew perfectly well what was going to happen, and when I listened after he got through his song, sure enough Dr. Bell said, "The audience couldn't hear a sound, Mr. Watson; you sing." Twenty years old and the most bashful boy you ever knew, but there was no help for it, I had to sing. Those girls looked solemn; I never blamed them, but I sang my whole repertoire and I could hear them applauding in New York. My baritone singer looked at me with disgust and said:

"Is that what you wanted?"

I said "Yes."

"Well," he said, "Boss, I couldn't do that."

Then he left.

One of our troubles in those lectures was that the telegraph wires in those days were not nearly so good as they are to-day. I doubt if we ever used a larger wire than No. 8, galvanized, and I doubt if they knew how to solder their joints. The wires themselves were rusted badly. After the first lecture or two, the telegraph operators all along the line found out that their relays would hum, when I was sending the intermittent current from the organ; every station on the line would cut in its relay. As our telephones were not adapted to work against any such retardation as that, we had trouble. One night Dr. Bell lectured in Lawrence, Mass., and I tried to give them the usual programme, but not one sound could I get through because half a dozen stations cut in along the line.

Those telephone lectures created a tremendous interest. I am always surprised when I think how intense and widespread that interest was. There were many applications for lectures, so many that Dr. Bell had to employ a special agent to look after the business. The man that he chose was a young newspaper reporter named Frederick Gower, the editor of the *Providence Press*, I think. As Mr. Gower was a man who loved to appear before the public and who lectured himself, occasionally, a dual lecture was arranged, I think in Hartford and New Haven. Dr. Bell lectured in one place and Mr. Gower in another; I, in between, at Middletown, furnished simultaneously for both lectures the usual illustrations, organ, cornet, voice, etc. Then the commercial demand for telephones took me away from the lectures and Mr. Gower got others to do the illustrating. At about that time, the day of Dr. Bell's marriage approached and he gave up lecturing, leaving the business in the hands of Mr. Gower, who carried it on a while longer. Soon after, Mr. Bell was married and went to England and my time became entirely absorbed by the commercial development of the telephone and the auxiliary apparatus. Mr. Gower had a contract for the exclusive use of the telephone in New England, but he was not handling the business very well, and one day Mr. Gardiner Hubbard asked me if I had any suggestion to make as to how he could get rid of Mr. Gower's contract. I suggested that he offer Mr. Gower the exclusive right to lecture on the telephone for the whole United States if he would give up his contract, and sure enough, Gower made the exchange. I think that gives one a good idea of the size of the telephone business at that time when a man with a contract for the whole of New England would give up that contract, worth to-day many millions of dollars, for the right to lecture on the telephone, a right that could not be conferred, anyway!

This course of lectures not only made possible Dr. Bell's marriage at that time, but it attracted capital to the telephone business and stimulated the commercial demand tremendously, and, more important than all, I believe it was a most important factor in determining the leasing of telephones instead of selling them outright, Mr. Gardiner Hubbard's plan, which made possible the uniformity of the Bell system to-day.

Ammonium Sulphate from Ammonia and Sulphur Dioxide*

Ammonia and Hydrogen Sulphide from Coal Gas and the Direct Production of Ammonium Sulphate

By Walter Feld

For the production of ammonium sulphate the by-product coke oven industry depends at present on the sulphuric acid industry, since the usual method of producing ammonium sulphate is based on the reaction between ammonia and sulphuric acid. This commercial inter-relation is at times very troublesome.

Evidently a great advance would be made if ammonium sulphate could be produced commercially and economically from ammonia and sulphurous acid. The advance would be great if the sulphurous acid were to be obtained from the roasting of sulphides. But the proposition would look even more promising and important if the sulphur contained in gasified coal and a large part of which passes into the gas as hydrogen sulphide, could be used directly for combining with the ammonia in the coal gas for the formation of ammonium sulphate.

For these reasons it is hardly surprising that for a long time attempts have been made to combine directly ammonia and sulphurous acid. Laming tried it as early as 1852 (British patent 14260). But he and others who worked along similar lines, overlooked that the reaction by which ammonia and sulphur dioxide combine will not proceed until it is complete. Neutral ammonium sulphite $(NH_4)_2SO_3$. H_2O gives off ammonia and the quantity of the ammonia given off increases with the temperature. The residue is a wet acid salt $(NH_4)_2SO_3$ which, in air, gives off sulphur dioxide, while only a small part is changed into sulphate. This whole behavior of the sulphites is due to the high vapor tension of both ammonia and sulphur dioxide and for this reason it is an impossibility to absorb *completely* ammonia contained in gases by means of an aqueous sulphurous acid solution or to absorb *completely* sulphur dioxide in gases by means of an ammonia solution.

But even if these difficulties could be overcome in practice (which seems impossible) the resulting salt would be of a very unstable nature. To use ammonium sulphite directly as a fertilizer (Lachomette's British patent 17050 of 1887) is impractical for more than one reason, especially on account of its tendency to give off sulphur dioxide and ammonia to the atmosphere. All attempts to change ammonium sulphite into ammonium sulphate by contact with air have been unsuccessful and must be so for good inherent reasons.

ABSORPTION BY TAR OILS.

For many years I have been interested in the reaction between sulphur dioxide and hydrogen sulphide, which is rather complicated, although the equation usually and probably erroneously assumed for it

$$2H_2S + SO_2 = 2H_2O + 3S$$

is simple enough.

In the course of our extended researches in this field, my collaborator, Mr. A. Jahl, established the fact that certain tar oils are excellent solvents for sulphur dioxide and sulphur.

Pure sulphur dioxide, introduced into heavy tar oils, is eagerly absorbed with a strong evolution of heat. If this is carried out in a closed bottle with shaking, the reaction is so energetic that the atmospheric pressure above the liquid is considerably reduced, while the temperature rises.

Now, if a tar oil has been saturated with sulphur dioxide and pure hydrogen sulphide is then passed into it, this is also completely absorbed, while simultaneously the temperature increases and the pressure decreases. In this reaction the sulphur dioxide and hydrogen sulphide react, forming sulphur and water, the sulphur dissolving in the hot tar oil.

If now the tar oil is treated alternately with sulphur dioxide and hydrogen sulphide, part of the dissolved sulphur will in time crystallize out of the saturated oil in crystalline grain form.

While this process appears to be very simple, yet it involves great difficulties when applied to gases which contain sulphur dioxide and hydrogen sulphide in great dilution.

ABSORPTION BY ZINC THIOSULPHATE.

Further experiments showed that hydrogen sulphide decomposes zinc thiosulphate in such a way that zinc sulphide and elementary sulphide are formed:

$$ZnS_2O_3 + 3\,H_2S = ZnS + 3\,H_2O + 4\,S.$$

If concentrated or dilute hydrogen sulphide is introduced into solution of ZnS_2O_3, the hydrogen sulphide is completely absorbed. In experiments carried out on a large scale with illuminating gas which was practically free from ammonia, one single washing apparatus was sufficient to absorb 80 to 90 per cent of the hydrogen sulphide in the gas by means of zinc thiosulphate solution.

The intention was to regenerate the ZnS_2O_3 from the zinc sulphide by means of sulphur dioxide, according to the equation

$$2\,ZnS + 3\,SO_2 = 2\,ZnS_2O_3 + S.$$

But this regeneration process does not work. First, the zinc sulphide is dissolved very slowly only in sulphur dioxide. Second, the regenerated zinc solution has lost most of its ability of absorbing hydrogen sulphids. The reason is that the regeneration process does not take place as had been supposed, since when zinc sulphide and sulphur dioxide react together, polythionate ZnS_4O_6, instead of the thiosulphate ZnS_2O_3, is mainly formed, and it is a fact for which good physico-chemical reasons may be given, that hydrogen sulphide acts strongly on zinc thiosulphate, but slightly only on polythionate.

In spite of these shortcomings, the process indicated a direction in which the work was to be done. It is especially noteworthy that a possibility of absorbing simultaneously hydrogen sulphide and ammonia from the gas was indicated according to the equation:

$$ZnS_2O_3 + 2\,NH_3 + H_2S = ZnS + (NH_4)_2S_2O_3.$$

As a matter of fact, experiments showed that not only hydrogen sulphide, but ammonia could be absorbed in this way.

ABSORPTION BY FeS_2O_3.

The regeneration difficulty in the use of ZnS_2O_3 is overcome by using the iron salt FeS_2O_3 instead of the zinc salt for absorption.

The gases which contain ammonia and hydrogen sulphide are washed with FeS_2O_3, whereby iron sulphides are precipitated.

$$FeS_2O_3 + 2NH_3 + H_2S = FeS + (NH_4)_2S_2O_3.$$

The iron sulphide is dissolved in sulphurous acid forming FeS_2O_3, which is again used for treatment of gases:

$$2FeS + 3SO_2 = 2FeS_2O_3 + S.$$

When the alternate treatment with gas and sulphur dioxide has been repeated several times, the content of the ammonium salt has increased to such an extent that the recovery of ammonium sulphate from the solution becomes profitable.

The thiosulphate is now changed into polythionate by treatment with sulphurous acid

$$FeS_2O_3 + (NH_4)_2S_2O_3 + 3SO_2 = FeS_3O_6 + (NH_4)_2S_4O_6$$

and then into sulphate by increasing the temperature

$$FeS_3O_6 + (NH_4)_2\,S_4O_6 = FeSO_4 + (NH_4)_2\,SO_4 + 2SO_2 + 3S.$$

The heating may be carried out simultaneously with the treatment with sulphurous acid so that the last reaction takes place practically simultaneously with the preceding one.

The formation of ferrous sulphate is accompanied by the formation of sulphur dioxide and free sulphur. The free sulphur is burned to sulphur dioxide, while the sulphate solution is again treated with crude gas:

$$FeSO_4 + 2(NH_4)_2\,SO_4 + 2NH_3 + H_2S = FeS + 3(NH_4)_2\,SO_4.$$

The ammonium sulphate solution is separated from the iron sulphide and concentrated by evaporation.

This process has proven practicable on a large com-

*Reproduced from *Metallurgical and Chemical Engineering*.

mercial scale and is being used at present in an illuminating gas plant and in a coke-oven gas plant, 60,000 to 70,000 cubic meters of gas being treated daily in each plant.

If there is an excess of hydrogen sulphide over ammonia, no special difficulty is experienced. Hydrogen sulphide alone, without ammonia, reduces ferrous thiosulphate to iron sulphide, according to the equation:

$$FeS_2O_3 + 3H_2S = FeS + 4S + 3H_2O$$

although the low speed of this reaction necessitates comparatively large apparatus when dilute hydrogen sulphide is treated.

On the other hand, the application of this process in such cases in which there is an excess of ammonia over hydrogen sulphide, is impossible without further serious complications.

POLYTHIONATE PROCESS.

In my researches on the physical and chemical properties of metallic thionates, I also paid considerable attention to the behavior of the sodium and ammonium salts. It was found that especially ammonium thiosulphate has the characteristic property of being very easily changed into polythionate by treatment with sulphur dioxide,

$$2\,(NH_4)_2\,S_2O_3 + 3SO_2 = (NH_4)_2\,S_4O_6 + (NH_4)_2\,S3O_6.$$

This reaction is rapid and complete so that sulphur dioxide may be completely and successfully washed out of dilute gases by treating these gases with ammonium thiosulphate.

Now, ammonium polythionate is a very effective means for washing out hydrogen sulphide and ammonia, either together or separately. The reactions are probably quite complicated. I, therefore, give only the final results.

$$(NH_4)_2\,S_4O_6 + (NH_4)_2\,S = 2(NH_4)_2\,S_2O_3 + S,$$

further

$$(NH_4)_2\,S_4O_6 + 3H_2S = (NH_4)_2S_2O_3 + 5S + 3H_2O,$$

and

$$(NH_4)_2\,S_4O_6 + 2NH_3 + H_2O = (NH_4)_2\,SO_4 + (NH_4)_2\,S_2O_3 + S.$$

In each of these three cases thiosulphate is formed, which is changed again by means of sulphur dioxide into polythionate according to our former reaction

$$2(NH_4)_2S_2O_3 + 3SO_2 = (NH_4)_2S_4O_6 + (NH_4)_2S_2O_6.$$

By an alternate treatment of the solutions with gas and sulphurous acid, the content of ammonium salts gradually increases. Finally by treatment with sulphurous acid and application of heat, the solution is changed into polythionate and finally sulphate.

$$3(NH_4)_2\,S_4O_6 = 3(NH_4)_2\,SO_4 + 3SO_2 + 6S,$$

and

$$2(NH_4)_2\,S_2O_3 + 3SO_2 + S = 2(NH_4)_2\,S_4O_6,$$

and by addition of the two equations

$$(NH_4)_2\,S_4O_6 + 2\,(NH_4)_2\,S_2O_6 = 3\,(NH_4)_2SO_4 + 5S.$$

That is, when the content of plythionate has reached a certain maximum, then the sulphurous acid which is set free during the sulphate formation, is sufficient to change the present thiosulphate into polythionate and then into sulphate. The precipitated sulphur grains are separated from the sulphate solution for the recovery of crystalline ammonium sulphate.

This polythionate process (British patent 5838 of 1911) represents the simple and reliable solution of the old problem of completely combining ammonia and sulphur doixide in coke-oven gas or illuminating gas for the production of ammonium sulphate.

In going over the reactions given above, it will be seen that no other oxidizing agent is used besides the atmospheric oxygen consumed for burning the sulphur dioxide. The simple furnace in which sulphur is burned to sulphur dioxide replaces completely the sulphuric acid factory which was hitherto a necessity.

PRACTICAL OPERATION OF THE POLYTHIONATE PROCESS.

Above is a diagram of the Feld polythionate process.

W is the washer,
W B the washer liquor tank,
R the regenerator,
O the sulphur oven,
S the air blower for the sulphur oven,
K the boiler,
C the centrifugal machine for separation of sulphur,
V G the tank for the final ammonium sulphate liquor,
E the vacuum boiler,
Z the centrifugal for separation of ammonium salt,

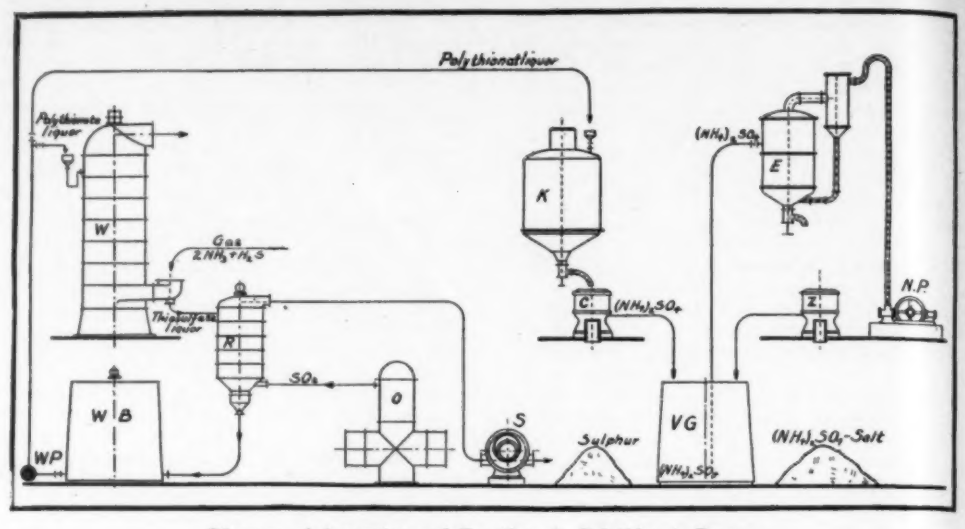


Diagram of Apparatus and Reactions in Polythionate Process.

and *N P* is a vacuum pump.

The polythionate liquor enters the washer *W* at the top and by the action of ammonia and hydrogen sulphide in the gas, is reduced into ammonium hyposulphate solution.

The hyposulphate solution coming from the washer enters the regenerator *R*, where it is treated with sulphur dioxide. By this treatment the hyposulphate solution is regenerated into polythionate. The polythionate liquor leaves the regenerator *R* and is run into the washing liquor tank *W B*. By the washing pump *W P* the liquor is circulated constantly, as above mentioned, through washer *W* and regenerator *R*, until the liquor has obtained such strength as is equivalent to 35 or 40 per cent of ammonium sulphate solution. Part of the concentrated polythionate liquor is now pumped into boiler *K*, and is here heated by steam. By this treatment the polythionate in the solution is decomposed into sulphate and free sulphur. The latter is separated out by the centrifugal separator *C*. The clear sulphate liquor is run into the storage tank *V G*, and from there into vacuum boiler *E*. By evaporation in the vacuum apparatus, crystals of ammonium sulphate are obtained, which are dried by the centrifugal apparatus *Z*.

This process is in successful operation in the Municipal Gas Works in Koenigsberg, Prussia, since June, 1911, dealing with a maximum production of 100,000 cubic meters (3,530,000 cubic feet) of coal per day.

The Structure of the Atom—I*

The Physical and Chemical Properties of the Atom Explained in the Light of Modern Theory and Experiment

By Sir J. J. Thomson, F.R.S.

THE atomic theory of matter involves the view that matter is not continuous, but is built up of individual particles. The theory is indeed as old as physical science itself, but, in spite of its antiquity, it is a fact that till quite recently the only methods which could be used to investigate it were indirect in character, and yielded results difficult to interpret. Within the last few years, however, other methods have been discovered for dealing experimentally with this theory, and these afford much more direct information as to the nature and properties of the atom. The improvement thus effected is almost entirely due to the fact that we have electrified the atom. This generation has electrified its railways and electrified its homes. The changes thus wrought have been great, but not more striking than those which have resulted from the electrification of the atom and the molecule. In its unelectrified state, the atom is most elusive. It requires a crowd of a billion (indeed this is hardly enough) to make up an amount the presence of which could be detected by the chemist. No chemical method can, in point of fact, deal with a smaller number than one billion. So soon, however, as an atom is electrified, it becomes very much more aggressive, pushing its way into such prominence that one electrified atom is as useful to the investigator as a million of unelectrified. As one result of the prominence thus attained, there has been an enormous gain in the ease with which the atomic theory can be studied, since an electrified atom finds it difficult to escape observation.

Before going on to study these methods, I wish to draw attention to certain characteristics of any atomic theory. The chief of these lies in the fact that whether the theory relates to matter, to electricity, or to energy, it implies that the subject of the theory is constituted by individual particles, the qualities of which, in place of varying continuously from one to the other, do so by jerks which can be detected by sufficiently refined means of observation. Were we able to study with sufficient minuteness drops of water, we should find that, if unequal, no two approach each other in weight by less than a certain value. The two would differ by a finite amount, the smallest value of which was equal to the weight of a molecule. This weight is infinitesimal in comparison with what is detectable by direct weighing, and it is not possible, by such a process, to get information as to the molecular state. Closely connected with this there is, however, another method, viz., that which enabled Dalton to lay the foundations of the modern atomic theory. Instead of attempting to detect the "jumps" in the weight of one kind of matter, he considered the "jumps" in the proportions of different kinds of matter in compounds. If two systems of individuals are taken, viz., A and B, compounds can be formed by uniting an individual of A with one of B, or one of A with two of B, or two of A with one of B, and so on. Then, if each A weighs as much as 12 B, the first compound, on analysis, would show that the proportions would be as 12 to 1; in the next the proportions as 6 to 1; and in the third as 24 to 1. In fact, whatever the compound thus formed, the proportion of the ingredients would be in the ratio of 12 p to q, where p and q were whole numbers. Hence the proportions of compounds could not vary continuously, but form series widely separated, at any rate for small values of p and q.

It was thus found that in all compounds of carbon with hydrogen the weight of carbon to hydrogen was in the proportion of 12 × one integer to another integer. With H and O the proportions were always as p to 16 q, with O to N as 16 p to 14 q. Hence it was concluded that there was, in the case of carbon, a unit with weight 12, with H a unit of weight 1, with oxygen a unit of weight 16, and with N a unit of weight 14. All these properties could be represented by assuming that chemical compounds were made up of individuals, each with its own weight. This was really the way by which Dalton arrived at the atomic theory of matter, and made it one of the tools of the chemist and physicist.

Great help in elucidating the theory has been derived from investigations into the theory of gases on the hypothesis that gases consisted of small particles moving with very great velocities. This idea has been studied by Bernoulli, Joule, Clausius, and Maxwell. A result of special interest is that equal volumes of gas (at the same pressure and temperature) contain the same number of individual systems. This result is known as Avogadro's law, viz., that each cubic centimeter of each gas contains the same number of molecules when the pressure and temperature are the same. If this law is accepted, it becomes necessary to have atoms as well as molecules. I can not prove this better than by recalling a conversation some twenty years ago between Sir George Stokes and a distinguished visitor, who was being shown over the Cavendish Laboratory. I was at the time engaged in some experiments there, and in discussing them spoke of atoms.

* First of a course of lectures delivered at the Royal Institution, London, and reported in *Engineering*.

To this the visitor took exception, declaring that while he admitted the existence of molecules, there were no such things as atoms. This assertion proved too much for Stokes, who joined in and gave a little lecture on the evidence for the existence of atoms as well as molecules. He said to his friend, "You admit Avogadro's law." "Yes," was the reply, "but there is nothing about atoms in that." "Take, then," said Stokes, "a liter of H and a liter of chlorine. Each contains the same number of molecules. If mixed together in the dark, 2 liters will be obtained, containing 2 *n* molecules of the mixed gases. Let the mixture next be exposed to diffused daylight. The result will be the formation of H Cl, which is another gas distinct from either H or Cl, but occupies the same volume as the uncombined gases. You say that nothing exists but molecules; but if so, the result of the combination should have halved the number present, and reduced the total volume accordingly to 1 liter instead of two. The only way to save Avogadro's law is to admit that each molecule of hydrogen and of chlorine divides into two, half of each going to form a molecule of the combined gas."

Admitting, then, that each element is made up of these individual systems, what evidence have we that in hydrogen, for example, each system is identical. Might it not be that the atoms and molecules of H have just an average value, some being less heavy, and others heavier than this average? It has, indeed, been maintained that in all the operations of the chemist, such as weighing, etc., the average of the atoms might well be constant, though the individuals might differ *inter se*. Direct information as to this has, however, now been obtained in the following way:

By electrifying atoms it is possible to follow the paths along which they move when traversing an electric and a magnetic field; and it is further known in what way this path depends upon the weight of the atom. If such electrified particles, before entering the electric and magnetic fields, are passed through a fine tube, a pencil of them is obtained, which, if allowed to fall on a photographic plate, traces thereon a series of parabolas. Each of these parabolas corresponds to a given weight of particle. If for a particular element the weight is not the same for each and every atom, we should get, instead of one parabola, a sheaf of parabolas. Actually, by making the sorting-tube (before the electric and magnetic fields) fine enough, the curves in the photographs can be obtained as fine as threads. This showed that the atoms of each element have each the same weight.

The very notion of the atom regards it as preserving some kind of individuality throughout its whole existence, whatever the combinations into which it enters, and however it may change its partners. In short, in such associations it changes its habits, but not its nature, though it is difficult sometimes to recognize the atom in its various partnerships unless the brutal methods of the chemist are adopted, and the compound split up to see what it is made of. The behavior of an atom depends much on its associates. Prussic acid and bread and water are both constituted of the same kind of atoms, but the properties of the two are by no means identical.

Again, oxygen when alone is strongly magnetic, but in combination with carbon is practically non-magnetic. Iron in many of its compounds is still magnetic, but it is non-magnetic in the ferricyanides, and, I believe, actually diamagnetic in iron carbonyl. Tyndall, again, has shown that both nitrogen and hydrogen are very transparent to heat, but the ammonia formed by their combination is very opaque. Hence, when in combination atoms may exhibit properties entirely different from their character when free. Another instance of the remarkable change of properties brought about by combination is afforded by sodium. Metallic sodium is very sensitive to the action of light, under the influence of which it gives off negative electricity, and can thus discharge a positively electrified body in its neighborhood. Coupling a rod, immersed in clean metallic sodium sealed into a glass tube, to a positively charged gold-leaf electroscope, Prof. Thomson showed that the latter retained its charge until a bright light was allowed to fall on the sodium. When this was done negative electricity was given off and the electroscope discharged. Next, by opening the tube and admitting the air the sodium was superficially oxidized, and he then showed that it had lost its property of emitting negative electricity when exposed to light.

Until a few years ago the sole property which an atom could be said to retain permanently was its weight. It is true that by Scott's law the volume of a compound is the sum of the volume of the elements, but to bring this hypothesis into accord with experiment, it is necessary to ascribe a different volume to the element, according to the way in which it was combined. Similarly, the refractive power of liquids is said also to be an additive property; but here again the value to be attributed to each element depends upon the character of its chemical combination. Hence, until recently, there was no property of the atom, save its weight, which had been proved to be invariably retained by it. Other properties have, however, now been found which are absolutely independent of the compound in which the atom exists, but depend only on the atom itself, and not at all on the others with which it is associated. One of the most remarkable of these novel properties is that of giving out characteristic Röntgen radiation. So far as ordinary light radiation is concerned, the radiative power of the atom is not independent of its chemical state. When, however, Röntgen rays fall on a piece of metal, the latter gives out Röntgen rays on its own account. Of these, some are the same in quality as the incident rays, but these do not constitute the characteristic radiation. In addition to these, however, each element gives out rays peculiar to itself, and this characteristic radiation is unchanged whether the elements are alone or combined, and the existence of a given element in a compound can be recognized in this way without having to split the latter up, it being merely necessary to submit the mass to Röntgen radiation, and to study the characteristic radiation then given out. Röntgen rays have very searching properties, but are not the only agent by which a knowledge of the inner structure of the atom can be attained. We can also use negative particles, which, owing to their enormous velocities, can be shot through different substances. In their passage they experience certain resistances, so that a fine pencil of rays is rendered fuzzy, just as light is by passing through a fog. This fuzziness is due to the effect of the reflection of the particle from each one of the atoms it meets with as it went through. Each, in fact, produces a certain deflection in the stream, and on measuring this for compounds and for simple bodies the amount is found to be constant for each kind of atom, whether present alone or combined. The atom can, in short, be recognized in compounds by the obstruction it offers to the passage of the β radiation. Again, compounds absorb Röntgen rays, and this absorption can be accurately calculated by assuming that each atom, whether combined or free, produces the same amount of absorption. Radioactivity is another phenomenon which remains the same, whatever the state of the radioactive atom.

The series of properties set forth above as retained by the atom in all conditions have, it would be seen, a close relation with agents which travel deeply into the body of the atom, whereas the properties which are altered by combination are of a superficial character. This leads to the conception that the atom consists of an outer shell and an inner one. The properties of the shell may be very radically changed when the atom passes from one compound to another, but the inner core remains wholly unaltered, so far as we know, in all physical and chemical changes.

Can anything be found out as to the substances of which an atom is built up? With merely chemical processes the same elements are obtained at the end as at the beginning of an investigation, and from this we can therefore learn nothing as to the structure of the atom. If, however, substances are exposed to certain physical changes, as by passing a current of electricity through them, then while the current passes, substances are found which are not present at the beginning, and which must have come from the atom. Thus if a current is passed through a highly exhausted gas, a greenish phosphorescence is produced on the glass of the bulb opposite the cathode. This phosphorescence has some peculiar properties; for example, it can be moved about over the surface of the bulb by bringing a magnet near it. It had been shown that the green patch in question is produced where certain very small particles shot off from the cathode strike the glass. The mass of these particles has been measured by methods described in previous lectures. It is found to be very small compared with that of any known atom, the best determination making it equal to 1-1700 the mass of the hydrogen atom.

These particles must have come from something in the tube, and it is found that whatever the tube is made of, and whatever it contains, the same particles are always found. It is thus concluded that these particles form part at least of what helps to build up the atom. These particles were, as stated, first recognized in the exhausted tube, but once known, it is easy to find them in all sorts of unexpected places. They are given off from hot wires, and liberated from metals exposed to the action of light. From radio-active matter they are shot out with prodigious velocities. There is, in fact, no material known which can not furnish them in apparently unlimited quantities, and however they are obtained, they are always identically the same. This fact constitutes strong evidence that these negative particles form part of any and every atom. Each, then, contains some of these, and it remains to consider what else the atom contains.

Before going on to this, however, I will illustrate a method by which the atoms in a given space can be counted, and the charge on each measured. This is founded on the rate at which small particles fall through air. [By throwing into a jar of glycerine three balls of the same material, but of different sizes, Sir Joseph showed that the largest fell the most rapidly, and he observed that by noting the rate at which each fell it would be possible to determine its weight. Naturally, with such relatively large masses more direct methods would be employed in practice; but the principle in question is applicable to the measurement of the size of the particles in a cloud, each of which was too small to be individually visible in the microscope. To illustrate this he exposed moist air in a long vertical glass cylinder to the action of radium. On then suddenly expanding the air a cloud formed, which settled down at a steady rate, and by measuring this rate, the lecturer said, it was possible to deduce the size of the particles forming the cloud.

(To be continued.)

Animals as Converters of Plant Nutriments Into Human Foodstuffs*

THERE are numerous circumstances under which questions of economy in the use of foodstuffs need to be taken into consideration. The problem of the cost of production of our nutrients is one that appears to be growing in importance and seriousness from decade to decade. In the extensive use of animal foods, so common in most civilized nations to-day, it is rarely borne in mind that the production of this type of nutrient involves a conversion of plant food into animal foodstuffs —a transformation inevitably necessitating a sacrifice of considerable energy. The animal which devours the plant products requires no small proportion of the stored energy for its own maintenance, that is, its normal life processes; accordingly the residue available for the production of meat and fat or the secretion of milk, which may become available to man as dietary articles, must represent a correspondingly smaller portion of the actual nutrients originally stored in the plant ingested. One is, therefore, justified in asking to what extent it may be possible or desirable for mankind to attempt to avoid this intermediate waste of energy by making direct use in larger proportion of the plant products which are ordinarily converted to our advantage by the herbivorous animal.

In attempting to answer this question we must bear in mind the diverse character of some of the plant products which are ordinarily consumed by man and the plant-eating animals, respectively. The latter utilize such natural products as straw, grass, leaves, etc., which ordinarily form no part of the human dietary. An inspection of these products reveals at once their relative richness in cellulose and related substances, which are not rendered available to the human individual in nutrition, but evidently are not without some nutrient value to the animals which consume them. Probably the most important factor in enabling the herbivorous animals to utilize such materials as have been referred to lies in the part played in them by certain types of alimentary bacteria which exert sufficient solvent action on the cellulose envelopes of various types of plant materials to liberate their more digestible contents for the subsequent action of the digestive juices of the animal, and, perhaps, also to convert the insoluble and unavailable cellulose into fermentation products which may still have a certain degree of nutrient value in the organism. At any rate it is clear, from such experimental evidence as is available at the present day, that cellulose is disintegrated in the alimentary tract of herbivorous animals to an extent which never occurs in the digestive tube of man. The only comparable factor which can enable the human organism to liberate the foodstuffs from their impervious coverings in the cereals, etc., is the process of grinding and milling which brings about an extensive comminution of these products.

It is interesting to note that all the vegetable foodstuffs which are easily digested by man are advantageously used directly in our diet. The ultimate value of animal production lies, in part, in the fact that it enables mankind to transform into more readily utilizable food products nutrient materials for which the human organism is not well adapted. It follows, therefore, that in order to furnish nutriment to the maximum population from the natural resources of the land, the more digestible vegetable products should be applied directly for the nutrition of man, whereas the more resistant ones should be converted to his use through the intermediation of the ruminating animals. The respective rôles of the two types of organisms ought to be constantly borne in mind.

* Reproduced from the *Journal of the American Medical Association*.

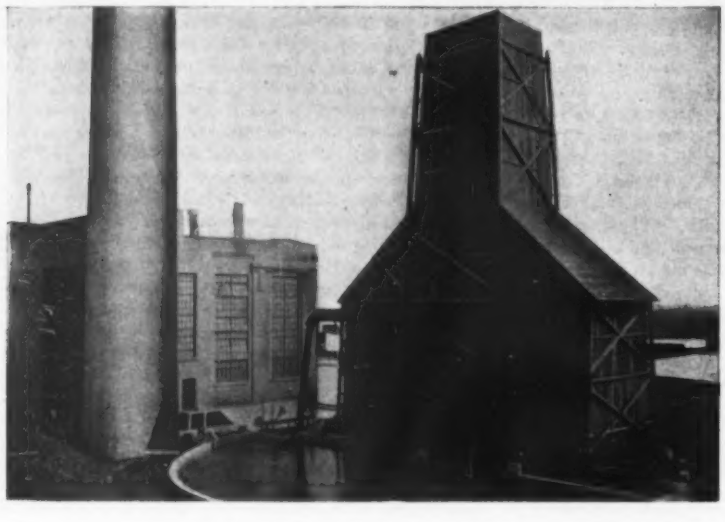


Fig. 1.—The economy of this tower is due to the fact that it operates on natural draft and therefore requires no power fans; that the water need be lifted to only the minimum height; and that the stacks cool the water on the drop and film principle.

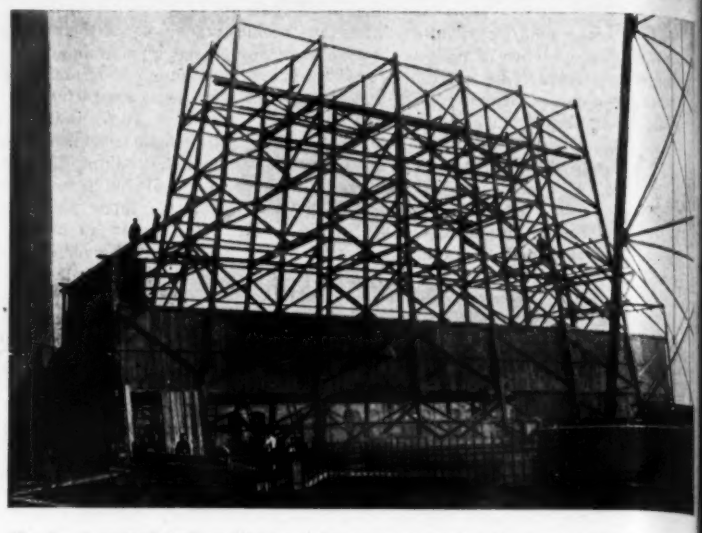


Fig. 2.—A natural draft cooling tower in course of erection for a plant at Canton, Ohio. This tower cools the condensing water from three Wheeler Surface Condensers. Its total capacity is 202,500 gallons of water per hour.

Cooling Towers for Industrial Establishments

Their Construction and Efficiency

THE substantial economies and advantages of the steam turbine, and especially the low-pressure steam turbine, have been demonstrated by repeated experiences in every type of steam plant. The low pressure turbine can almost double plant capacity without the addition of boilers, stacks, fuel or labor.

But the condensing water necessary is scarce in the case of many central stations, electric railway plants and especially factories, mills and industrial plants.

In such locations the use of apparatus for recooling the condensing water permits of operating condensing with or without low-pressure turbines. A cooling tower is the device most often used because of its greater efficiency as compared to spray nozzles or ponds, and its simplicity and compactness. A properly designed water cooling tower thus becomes equivalent to a natural water supply.

If it operates with natural draft and no fan is used, the only item of operating expense is the cost of lifting the water to the distributing system and this lift may be greatly reduced by proper design of the cooling stacks over which the water falls.

The primary essentials for effective cooling are large capacity for dissipating heat to the atmosphere so that a large volume of water is cooled, and ability to dissipate this heat at low temperature so that the water is cooled to a low temperature. To accomplish this, the water must present an extensive cooling surface to the air rising within the tower, and secondly there must be a brisk and vigorous air circulation. These essentials are secured in the tower to be described by arranging the cooling stacks in zigzag tiers which, while retarding the downward flow of the water, present but little resistance to the upward flow of the air. The cooling laths retard the downward flow of the water, and spread it out into thin films, collect it and break it up into drops, so that an extensive and ever-changing water cooling surface is presented to the air. This method of cooling is known as the "drop and film" principle.

CONSTRUCTION OF THE WHEELER-BALCKE TOWER.

Fig. 3 shows the construction of a natural draft, chimney type tower. Starting at the top, we have first the vapor outlet, beneath that the chimney, next the water distributing system which receives the water to be cooled from the water inlet pipe, and discharges it evenly over the whole surface of the tower. Beneath the water distributing system are the cooling stacks and the air inlets and finally at the lowest point the cold water well, in which the water is collected, and from which it is drawn to the condenser.

The chimney and vapor outlet are of cypress boards, supported by a frame work of yellow pine, resting directly upon the foundation. The chimney is of sufficient height to prevent loss of water by spray, and to draw a strong natural draft and a vigorous flow of air through the cooling stacks. The timbers forming the frame of the tower and chimney are especially treated to prevent deterioration. The frame is constructed with mortised and tenoned joints where necessary, bolted together with steel bolts with large iron washers on each side, thus making a rigid and substantial frame to withstand a fifty-mile wind pressure. The shell of the chimney and the tower consists of surfaced tongued and grooved one-inch cypress boards as free as possible from large, loose and dead knots, shakes and other imperfections, treated after erection with a special wood preservative to prevent decay.

Special attention is drawn to the water distributing system. The main trough into which the water is discharged from the water inlet is of cypress planks 1½ inches thick, from which the water flows into lat-

TABLE I.

Test of Cooling Tower at West Pullman, Ill.

Test No.	DATE 1912. Sept.	WATER G.P.M.	WATER Temp. In	WATER Temp. Out	AIR Temp. In	AIR Temp. Out	AIR Humidity. In	AIR Humidity. Out	WEATHER.
2	11	1,230	112	87	71	99	69	100	Strong wind.....Cloudy
3	11	1,230	112	85	71	102	56	100	" " ..... "
4	11	1,230	111	86	69	96	64	100	" " ..... "
5	12	1,230	105	83	71	93	56	100	Light breeze.....Clear
6	12	1,230	106	81	74	95	56	100	" " ..... "
7	12	1,230	106	82	77	97	49	100	Brisk " ..... "
8	12	1,230	106	82	78	96	49	100	" " .....Cloudy
9	13	1,200	102	82	74	91	47	100	Light " .....Clear
10	13	1,200	103	81	75	93	47	100	" " ..... "
11	16	2,100	97	83	65	92	73	100	" wind..... "
12	16	1,700	101	83	68	95	62	100	" " ..... "
13	16	1,520	104	85	72	94	57	100	" " .....Cloudy
14	16	1,520	104	85	70	95	68	100	" " ..... "
15	17	1,620	99	82	63	92	84	100	No breeze ..... "
16	17	1,280	106	82	63	96	84	100	" " ..... "

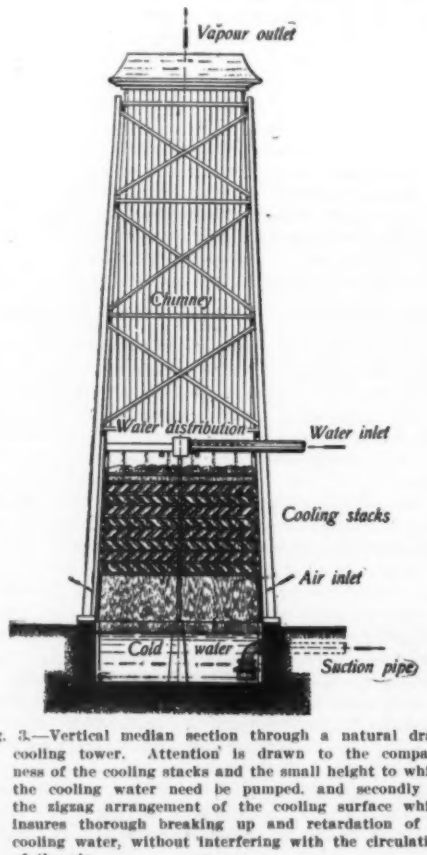


Fig. 3.—Vertical median section through a natural draft cooling tower. Attention is drawn to the compactness of the cooling stacks and the small height to which the cooling water need be pumped, and secondly to the zigzag arrangement of the cooling surface which insures thorough breaking up and retardation of the cooling water, without interfering with the circulation of the air.

eral gutters, which in turn distribute the water over the entire area of the tower by iron pipes arranged at equal intervals in the length of the gutters. The water falling from these pipes impinges upon galvanized steel splash plates, which break the water into a fine spray, presenting to the rising current of air a cooling surface of maximum area. The water then drops upon the triangular cooling laths below, which are arranged in zigzag tiers, as shown in the drawing. The water is continually broken up, turned over, spread out in a thin film and retarded in its downward progress so that the greatest possible amount of surface is exposed to the rising current of air. The zigzag arrangement of cooling laths insures thorough breaking up and turning over of the water without presenting high resistance to the rising column of air.

The cooling laths are supported by a frame work independent of the tower and chimney, and consist of well selected cypress, practically free from loose or dead knots. Cypress being practically indestructible in water, the life of the tower is almost unlimited. Data regarding the life of cypress wood may readily be obtained from government publications, which cite, for instance, a case where a well selected grade of swamp cypress lasted in first-class condition for over eighty years. The air enters the tower near its base, louvre boards being used to prevent loss of water by splashing, diverting it instead into the cold water well. The cold well also forms the foundations for the tower and may be made of concrete or masonry, as desired by the purchaser. A working platform with hand rail is built on one side of the tower. The platform is reached from the ground by means of a strong ladder, also providing with hand rail. Entrance is effected into the tower by means of a door, which is made part of the shell. The distributer may be cleaned out by a broom while the tower is in service.

In very large towers the multicellular design is used

TABLE II.

Test of Cooling Tower at Bristol, Conn.

Test No.	DATE 1912. Aug.	WATER G.P.M.	WATER Temp. In	WATER Temp. Out	AIR Temp. In	AIR Temp. Out	AIR Humidity. In	AIR Humidity. Out	WEATHER.
1	13	850	114	84	84	..	62	100	Light breeze.....Hot
2	15	877	104	86	80	95	51	100	" " .....Cloudy
3	16	880	94	76	68	84	47	100	" " .....Clear
4	16	1,065	92	75	70	83	37	100	" " ..... "
5	16	1,058	100	74	70	91	37	100	Brisk " ..... "
6	26	850	114	87	81	99	76	100	Light " .....Hazy
7	27	850	104	80	77	95	48	100	Brisk " .....Cloudy

as shown in Fig. 4. Owing to the resistance of the falling shower of water, air will not penetrate to the center of a large tower, and the water in that region will not be cooled as efficiently as that falling in other parts nearer the shell. By the multicellular arrangement, air is evenly distributed to all parts of the tower, and the water in the center is cooled to a low temperature, so that the average cold well temperature is the minimum compatible with atmospheric conditions.

INSTALLATION AT WEST PULLMAN, ILLINOIS, PLANT OF THE INTERNATIONAL HARVESTER COMPANY.

The photograph of Fig. 1 shows a tower of 72,000 gallons per hour cooling capacity, installed at a works in West Pullman, Ill. As may be seen from the picture, the tower is erected over a concrete reservoir which is large enough for a second tower of equal size. The reservoir is 75 feet in diameter and has a capacity of 600,000 gallons, forming a large cold well and also a reserve supply of water for the fire pumps.

The cooling tower operates in connection with two jet condensers. The tail pumps discharge directly to the distributors of the cooling tower through the pipe which may be plainly seen. The low elevation of the distributors may be estimated from the height of this pipe. The base of the tower is somewhat above the elevation of the turbine room floor, and is at a considerably higher elevation than the condensers which are in the basement beneath the turbine. Flooding of the condensers in case of failure of the vacuum is prevented by siphons in the suction lines.

Table I is a summary of a number of tests on this tower. It will be noted the air leaves the tower fully saturated (100 per cent humidity). This condition is characteristic of towers of this type, and is highly desirable for several reasons:

1. Saturation of the air means that the minimum amount is used. 2. The reduced volume of air means less loss in friction. 3. The draft produced by the chimney is greater because saturated air weighs less than dry air.

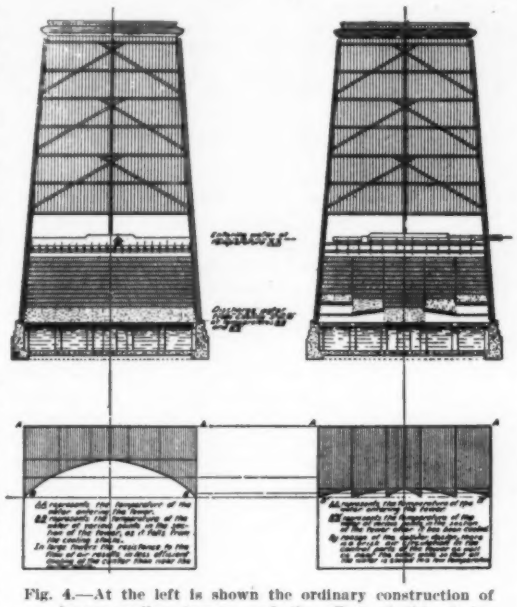


Fig. 4.—At the left is shown the ordinary construction of larger cooling towers, and the effect of this design on the temperature of the water is indicated by curve *BB*. The multicellular design of large cooling towers is shown at the right. By this arrangement efficient cooling is obtained in the central portions of the tower as well as near the outer walls, the water temperature being indicated by *B'B'*.

Tests 15 and 16 can be selected as showing the efficiency with which cooling is secured, even with high humidity of entering air. Referring to the table, it will be seen that the humidity was 84 per cent in each case, the temperature of the air being 63, and that in the case of test 15, the cooling was from 99 to 82, and in test 16, from 106 to 82.

About two weeks after the date of these tests with atmospheric conditions slightly more favorable on a moderately warm but dry afternoon, the tower was supplying ejection water at about 72 degrees temperature, so that the vacuum on the turbine was but slightly lower than 28 inches. It is evident that vacuums above 28 inches will be maintained throughout the colder months of the year.

INSTALLATION AT BRISTOL, CONNECTICUT.

Another natural draft cooling tower of the type here described is installed in a plant at Bristol, Conn. This tower is 70 feet high, 44 feet long and 24 feet wide, and supplies the cooling water to a surface condensing equipment, operating in connection with a 750 kilowatt turbo generator.

A significant feature of this installation is that the tower is located near the banks of a stream of fair size, from which it would seem that an ample supply of cooling water could be obtained. The cooling tower was installed, however, because the quality of the water is poor, and is contaminated with sewage and acids, and because the supply falls very low in the summer.

The design of this tower is essentially similar to that already described. The chimney in this case is a straight continuation of the frame and shell, whereas the tower previously described has a tapering uptake between the tower proper and the chimney.

The results of tests made in August on the Bristol tower are given in Table II. Here again it will be noted that the humidity of the air leaving the tower is 100 per cent. The temperature of the water leaving the tower is remarkably close to the air temperature, differing by only a few degrees.

INSTALLATION AT CANTON, ILLINOIS.

The photograph of Fig. 2 is produced to further illustrate constructional features of these towers. The photograph shows a cooling tower of a capacity of 200,000 gallons per hour in the course of erection at the plant in Canton, Ill., where it handles the condensing water from three surface condensing equipments. This tower has several times the capacity of those described above, and is one of the largest towers ever built in this country.

Peroxides and Per-Salts—III

Their Preparation, Properties and Uses in the Arts and Industries

By A. S. Neumark

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 1948, Page 201, March 29, 1913

ALKALINE EARTH AND ALLIED PEROXIDES.

THE most important of this group of peroxides is barium peroxide BaO_2, as it forms the material from which nearly all hydrogen peroxide is manufactured; it has also been used, prior to the introduction of liquid-air oxygen, for the technical production of this gas by Brin's process.[1] As this compound is already well known we shall confine ourselves to some of the more recent applications which have been found for BaO_2. The peroxide is chiefly prepared by passing oxygen, or air freed from carbonic acid and moisture, over gently heated barium oxide. By adding hydrogen peroxide to a concentrated solution of barium hydrate, a hydrated barium peroxide is formed, having the formula $BaO_2.8H_2O$. This substance is only slightly soluble in cold water, but is decomposed by boiling water, forming barium hydrate and oxygen.

Barium peroxide is used as a bleaching agent for silk, straw and feathers. Tessié du Motay proposed the following method of bleaching tussah silk. The goods are worked for about 1 hour in a bath heated to 90 deg. Cent. and containing 50 to 100 per cent of barium peroxide referred to the weight of the silk. It is then passed through diluted hydrochloric acid and washed. For bleaching straw hats a preparation containing 83 parts of hydrated BaO_2, 17 parts of sodium bisulphate, and 8.8 parts of borax has been recommended. Ostrich plumes are bleached by immersing into a bath consisting of 10 parts barium peroxide and 1,000 parts of water and heating to 30 deg. Cent. The feathers are allowed to remain in the bath for 48 hours, when they are washed, passed through a weak hydrochloric acid solution, and dried. A mixture containing barium peroxide and paraform (polymerized formaldehyde) is on the market as a disinfectant. It forms formaldehyde and water vapor when brought in contact with water, heat being generated at the same time. Barium peroxide is also used in the manufacture of lithopone to prevent its darkening when exposed to sunlight. It is not used, however, in therapeutics on account of the poisonous nature of barium salts.

CALCIUM PEROXIDE, CaO_2.

A calcium peroxide containing molecular water, $CaO_2.8H_2O$, was first prepared by Thenard by the action of hydrogen peroxide upon lime water. Subsequently it was obtained by adding lime water in excess to an aqueous solution of sodium peroxide, acidulated with nitric acid. It is also obtained by adding a neutral or alkaline solution of Na_2O_2 to a solution of a calcium salt. Franz Fuhrmann[2] proposed the following method: 8 kilogrammes of sodium peroxide are mixed with 30 kilogrammes of hydrochloric acid and 10 liters of water, after which enough milk of lime (corresponding to 7.6 kilogrammes of calcium hydrate) is added; it is then permitted to stand aside, filtered and dried.

The commercial calcium peroxide is free from molecular water and represents a mixture of CaO_2, calcium hydrate and calcium carbonate. It is a light cream-colored, odorless and tasteless powder and contains not less than 60 per cent of the peroxide (equivalent to 13.4 per cent available oxygen).[3] Products containing 80 to 85 per cent of peroxide are also on the market. Calcium peroxide is practically insoluble in water, but on prolonged contact with water it is gradually decomposed, forming calcium hydrate and hydrogen peroxide. Complete decomposition is only obtained by heating. It is soluble in acids, the corresponding calcium salt and H_2O_2 being formed. A peroxide of the formula $CaO_2.2H_2O$ is also known. On account of its large proportion of available oxygen and its property of forming many insoluble salts, calcium peroxide has found many industrial applications. R. v. Foregger[4] proposed the use of this substance as a means of sterilizing drinking water on a large scale. Compared with the ozone process, the cost of using calcium peroxide is said to be slightly higher for large plants, but for small plants the use of this peroxide offers advantages in cost. This method has also the great advantage of simplicity, there being practically no machinery required; sterilization is also accomplished in less time than by the use of ozonized air. Like hydrogen peroxide, the calcium peroxide is also suitable for the sterilization of milk. The pure lactic acid present in milk decomposes CaO_2, forming calcium lactate and active oxygen. Erlenstein recommends a compound containing cellulose (or any other insoluble substance), gum arabic and calcium (or magnesium) peroxide, pressed into blocks, for sterilizing water or milk. Calcium peroxide forms an excellent ingredient for dentifrices. A tooth powder containing CaO_2 may be obtained by adding the latter to calcium carbonate, mixed with small quantities of magnesium carbonate and orris root; if a paste is desired, glycerine should be added. Calcium peroxide also forms an ideal bleaching agent for oils; the powdered CaO_2 is added in small quantities to the oil and the available oxygen is liberated by means of concentrated sulphuric acid. The use of calcium peroxide has further been proposed for preserving cider and for aging alcoholic beverages; fusel oils are eliminated by means of this substance.

STRONTIUM PEROXIDE, SrO_2.

Like the calcium salt, strontium peroxide contains molecular water, having the formula $SrO_2.8H_2O$. The

[1] SCIENTIFIC AMERICAN SUPPLEMENT, October 14th, 1911, p. 255.

[2] U. S. patent 861,826 of 1905.

[3] New and non-official remedies 1911, p. 234.

[4] Paper read at the Eighth General Meeting of the American Electro Chemical Society, 1905.

commercial product contains at least 84.5 per cent of calcium peroxide (equivalent to 11.3 per cent of available oxygen); it forms a white odorless and tasteless powder, is stable, and is decomposed by water without the addition of acids. It is used an an ingredient of dentrifrices, having a bleaching as well as a disinfectant action on the teeth. It also forms an ingredient of certain ointments and dusting powders.

MAGNESIUM PEROXIDE MgO_2.

Magnesium peroxide may be obtained by the interaction of an alkali peroxide on a magnesium salt. According to Merck, a peroxide containing 42 per cent of actual MgO_2, is prepared by adding magnesium oxide to hydrogen peroxide. Kirchhoff and Neirath have patented the following process: An acid solution, e. g., of hydrochloric acid is neutralized with sodium peroxide and to the saline solution of hydrogen peroxide resulting, is added magnesium chloride and then ammonia, with precautions against rise of temperature; magnesium peroxide is formed as a precipitate. A. Krause obtains the peroxide from sodium peroxide and magnesium sulphate, the liquor being treated with ammonium salts, and the liberated ammonia quickly expelled either by the passage of a current of air (devoid of carbon dioxide) or by the aid of a vacuum. The substance obtained is said to contain nearly 27 per cent of MgO_2. A magnesium per hydroxide $MgO(OH)_2$ is also known and is used as a bleaching powder.

Commercial magnesium peroxide is a mixture consisting essentially of MgO_2 and magnesium oxide with water of hydration. It contains not less than 15 per cent of actual MgO_2[5], and forms a white, amorphous powder. It is practically insoluble in water, but in suspension (milk of magnesium peroxide) is gradually decomposed into magnesium hydroxide and hydrogen peroxide, the latter being further decomposed by the alkalin hydroxide with liberation of oxygen. It is fairly stable, although subject to the influence of carbon dioxide.

Magnesium peroxide has proved a most excellent internal therapeutic agent. Its main value consists in the property of promoting metabolism. It is of value as a gastric and intestinal antiseptic. Pronounced results have also been obtained in the treatment of gout, rheumatism, obesity, acute and chronic constipation, catarrh of the stomach and intestines, gastric headaches, chlorosis, anemia; and has also been recommended in treating pyrrhea. It has mild laxative effects; together with citric acid[6] it forms what may be called an "oxygenated magnesium citrate." European practitioners use it in combination with Seidlitz's powder. Magnesium peroxide preparations are known abroad under the trade names of magnesium perhydrol, magnodate and hopogan. Magnesium peroxide is also used as an ingredient of dentrifices. As a tooth powder the following mixture has been recommended: magnesium peroxide 10 parts, soap powder 2.5 parts, calcium carbonate, powdered, 87.5 parts, oil of rose 0.25 part, oil of wintergreen 0.5 part and menthol 0.1 part. Magnesium peroxide, too, forms an ideal means of sterilizing drinking water; a mixture of 0.2 gramme of the peroxide with tartaric acid 0.5 grammes has been recommended for this purpose. Experiments made in that direction by Dr. Park of the New York Health Department showed that two tablets (containing each 0.10 gramme MgO_2 and a like amount of tartaric acid) would kill 2,250,000 typhoid bacilli in 150 cubic centimeters of distilled water in one minute. This means of sterilizing drinking water is especially recommended where instantaneous action is required, i. e., for the soldier in the field, for the tourist in tropical countries, etc. Magnesium peroxide also forms an admirable preservative for fruit syrups, replacing salicylic or benzoic acids.

ZINC PEROXIDE, ZnO_2.

The methods of preparation of this peroxide are identical with those of magnesium peroxide. Merck's product contains 60 to 61 per cent actual peroxide (zinc perhydrol). Other zinc peroxide preparations are on the market as zincodate, ektogan (50 to 60 per cent ZnO_2), etc. Zinc peroxide forms a dense yellowish-white powder and is very stable. It is only very slightly soluble in water but readily soluble in acids; it is odorless, non-irritant and has highly antiseptic properties. On account of the poisonous action of zinc solutions the uses of the peroxide are confined to surgery and dermatology as an ingredient for ointments, soaps and powders. Hydrogen peroxide cannot be used in oxygenated preparations, as it is soon decomposed, but zinc peroxide forms an excellent constituent for such. Ointments and powders containing this peroxide are valuable in the treatment of wounds, burns and skin diseases, especially in chronic eczema. For the latter purpose a mixture containing zinc peroxide 10 parts, potassium iodide 5 parts and tartaric acid 1 part, has been recommended; on moistening, iodine is gradually liberated.

An aluminium peroxide of the formulæ $Al_2O_3.Al_2O_4.10H_2O$ has recently been prepared by treating a concentrated solution of freshly prepared potassium aluminate with an excess of a 30 per cent solution of H_2O_2. It forms a light amorphous powder, having all the properties of a true peroxide.

PERBORATES.

Perborates are salts of perboric acid, HBO_3. A number of these salts are known. The most important is sodium perborate, as it is easily obtainable and of unlimited stability. The first research on perborates appeared in 1898, but it was fully six years before the practical value of these preparations was recognized. With water, the perborate form hydrogen peroxide; on treating with concentrated sulphuric acid they furnish a highly concentrated solution of H_2O_2, which at once decomposes with liberation of ozone.

SODIUM PERBORATE, $NaBO_3$.

Sodium perborate was for the first time prepared in 1898 by Tenaton at the laboratory of the University of Odessa, by treating a borax solution with a solution of hydrogen peroxide and caustic soda. Since then it has been obtained by a number of methods. It is formed by electrolyzing a solution of sodium ortho-borate. C. v. Girsewald[7] recommends the following method of preparation: 76.5 parts of technical borax and 21.6 parts of caustic soda (90 per cent) are dissolved in water, whereupon 950 parts of a 3 per cent solution of hydrogen peroxide is added, followed by a solution of sodium chloride (50 to 60 parts). The temperature is kept below 10 deg. Cent. The perborate crystallizes on cooling to 0 deg. Cent. A process which produces sodium perborate under conditions which render its manufacture of commercial value is, according to the *Deutsche Gold und Silberscheide Anstalt*, carried out as follows: Molecular proportions of sodium peroxide are allowed to react in the presence of water on boracic acid and an equivalent of an acid that yields a readily soluble alkali salt. The vessel in which the reaction takes place is cooled and the precipitated perborate is separated from the liquor. Or an aqueous solution of an alkali peroxide is treated with boracic acid (or an alkali borate) and carbon dioxide (or an alkali bicarbonate). The vessel used must be kept cooled by ice or ice water. The perborate is obtained as a precipitate. The reaction which takes place is shown in the following equation:

$$H_2BO_3+Na_2O_2+CO_2=NaBO_3+NaHCO_3+3H_2O.$$

According to another patented process[8] sodium peroxide, boric acid and a suitable zinc or magnesium salt are allowed to react in aqueous solution. The following methods have been recommended by Jaubert: 10.94 kilogrammes of pure concentrated sulphuric acid are mixed with 170 liters of water, the liquor being kept cool with the aid of ice water. Then 16.25 kilogrammes of sodium peroxide and 12.5 kilogrammes of boric acid are gradually added, care being taken that the temperature does not rise above 20 deg. Cent. Or boric acid is treated with sodium and hydrogen peroxide: $2H_3BO_3+Na_2O_2+H_2O_2=2NaBO_3+4H_2O$. This equation shows that no by-product is formed during the reaction. Sodium perborate may also be obtained from borax by treating with sodium and hydrogen peroxide: $Na_2B_4O_7+Na_2O_2+3H_2O_2=4NaBO_3+3H_2O$.

The perborates known are of varying composition. The monohydrate $NaBO_3.H_2O$ contains 16 per cent of active oxygen; a bi- and tri-hydrate is also known. The perborate of the formula $NaBO_3.4H_2O$ (having four molecules of water of crystallization) contains 10.4 per cent of active oxygen. An anhydrous sodium perborate is also known and is obtained from the perborate by prolonged desiccation *in vacuo* over phosphorus pent-oxide. It is extremely stable and especially suitable for export and for use in tropical climates. A perborax of the formula $Na_2B_4O_8.10H_2O$, which is more soluble in water than the perborates is, according to Jaubert obtained in the following manner: 248 parts of crystallized boric acid are mixed with 78 parts of sodium peroxide and into this mixture are gradually stirred 2,000 parts of cold water. The liquor is allowed to cool off, when the perborax precipitates as a snow-white crystalline powder which is filtered and washed with alcohol.

Sodium perborate forms an excellent substitute for hydrogen peroxide, being more stable than the latter and allowing the instantaneous production of a high-grade hydrogen peroxide solution. The perborate containing 10.4 per cent available oxygen corresponds to a 21 per cent hydrogen peroxide solution. In acid solution a hydrogen peroxide of 50 volume strength may be obtained. Dissolved in water sodium metaborate is formed at first which, being unstable, is soon transformed into borax. The reaction may be expressed by the following equations:

(1) $NaBO_3+H_2O=NaBO_2+H_2O_2$,

(2) $4NaBO_3+CO_2=Na_2B_4O_7+Na_2CO_3$.

By dissolving 170 grammes of the perborate and 60 grammes of citric acid in 1 quart of water a neutral 10-volume per cent solution is obtained which, in its antiseptic action, s at least as strong as that of the usual hydrogen peroxide solution. To improve the keeping quality of the perborate, the addition of certain substances has been recommended. Thus a stable mixture may be obtained by mixing the sodium perborate, partly deprived of its water of crystallization, with solid acid substances (other than boric acid). According to Powson & Co. tablets yielding an alkaline solution of hydrogen peroxide may be prepared by mixing the perborate, containing the normal quantity of water of crystallization, with dry acids or acid salts and sodium bicarbonate. According to another process[9] a stable compound is obtained by quickly fusing together 100 parts of sodium perborate with 5 parts of sodium bisulphate at 55 deg Cent. Sarason recommends the addition of sodium pyrophosphate to make the perborate more stable toward catalysts and the influence of heat. A solid preparation which evolves oxygen on addition of alkalies has been patented by C. J. Hoepner and is prepared as follows: 10 parts of sodium perborate are stirred into 20 parts of a solution of sodium silicate (38 deg. Bé). To this mixture are added 10 parts of water quickly followed by a solution of 2 parts of sulphuric acid (60 deg. Bé.) in 24 parts of water. The whole is stirred until gelatinized and is then allowed to stand aside for 12 hours at 15 deg. Cent.

Sodium perborate is of considerable therapeutic value. Being an alkaline preparation it has the advantage over hydrogen peroxide of not being irritating to the mucous membranes. Applied to open wounds, cuts, bruises, the powder acts as a powerful styptic. Its solution considerably hastens the healing process of fresh wounds; it has been especially recommended in the treatment of badly infected, fetid, gangrenous and soiled wounds. A 1 to 2 per cent solution is of sufficient strength as an antiseptic or disinfectant; on the surface of the skin it acts as a cleanser, deodorant, sweat absorber and even as a bleaching agent. A 1 to 1½ per cent solution is sufficient for a nasal douche or gargle. Taken internally the perborate is valuable in rectifying abnormal processes of fermentation in the stomach. It forms an excellent substitute for boric acid in diseases of the ear. Many oxygen toilet preparations are now on the market which contain sodium perborate. "Pergenol" is a preparation containing sodium perborate and sodium bitartrate in molecular proportions and is used as a mouth wash.[10] A preparation containing 1,000 grammes of sugar of milk, or sodium bicarbonate (or 500 grammes of each), and 50 grammes of sodium perborate, to which is added a suitable essence (e. g., 10 to 15 grammes oil of peppermint, 2 grammes oil of anis seed, etc.), is made up in tablets and employed for a like purpose. An oxygenated nail powder may be obtained by mixing 30 grammes of putty powder, 2 grammes sodium perborate and 1 gramme carmine, perfumed as desired; another manicure preparation is composed as follows: zinc oxide 30 parts (by weight), talcum powder 15 parts, sodium perborate 4½ parts and carmine, powdered, ½ part. As an ingredient to talcum powder the perborate would prove of threefold benefit: (1) its oxygen disinfects and destroys putrefaction; (2) the alkaline base neutralizes the acidity of perspiration and (3) it is a perfect deodorant. The following formulæ has been suggested by R. v. Foregger: talcum 94 parts, sodium perborate 5 parts, violet 1 part. Sodium perborate has also been recommended for perspiring feet. It is an ideal preparation for oxygen baths. Formerly compressed oxygen had been used for that purpose. But the gas bubbles obtained from tank oxygen are too large and rise too rapidly to the surface to be effective. In 1904 Sarason, of Berlin, conceived the idea of directly generating oxygen in the bath itself. He first used hydrogen peroxide, but later brought on the market his "Ozet" bath. Sodium peroxide has been found unsuitable on account of its caustic nature. Elkan recommends the addition of free iodine, or potassium iodide, to the peroxide or perborate. The globules of oxygen obtained from perborates are very small, being formed by chemical action; they readily cover the skin and the walls of the tub and rise but slowly to the surface, therefore dissolution of the highest percentage of gas is obtained.[12] Manganese is used as a catalyzer in Sarson's "Ozet" bath. To prepare the bath, 300 grammes of sodium perborate are dissolved in the bath, and 1 minute before the patient enters, 15 grammes of manganese borate are added. Effervescence begins at once, the process lasting 20 to 25 minutes. In the "Ozet" bath the water turns brown and leaves a fine, slimy mud, covering bather and tub, due to the formation of manganese dioxide. This rather unpleasant feature has been overcome in the "Perogen" bath. Catalytic substances which have been recommended in connection with oxygen baths are potassium permanganate, metal saccharates, enzymes and ferments of animal organisms, blood, yeast, fibrin and hæmoglobin. The admixture of glycerine and gum arabic to the perborate has also been recommended. According to Dr. Biedert,[13] oxygen baths regulate strengthen and quiet the heart. They reduce abnorma-

[5] *Jour. Soc. Chem. Ind.*, January 19th, 1906.

[6] R. v. Foregger, Peroxygen Bull., No. 3.

[7] German patent 204,279.

[8] English patent 26,790 of 1904.

[9] German patent 249,325 of 1908.

[10] *Apotheker Zeit.*, 1909, p. 664.

[11] *American Druggist*, 1906.

[12] *Post Graduate*, 1909, p. 909.

[13] *British Medical Journal*, August 17th, 1911.

augmentation of blood pressure, rate of pulse and respiration.[13] They are helpful in cases of tabes, bronchial asthma and have a general sedative effect on the nervous system. They also have a decided and reliable soporific action and a soothing and indirectly stimulating influence, besides exerting their oxidizing and disinfecting action on the skin.

Sodium perborate is doubtless one of the best bleaching agents known; standing in its efficiency between hydrogen peroxide and sodium peroxide. According to a patented process,[14] sodium perborate may be adapted as a practical bleaching agent by the addition of bases or salts of magnesium, the alkali earths or zinc, or the salts of hydroflur-silicic acid. Thus the addition of one sixth of a molecular proportion of calcium chloride has been found to make the solution stable up to about 87 per cent, heating being carried out at a temperature of 70 to 80 deg. Cent. For bleaching fabric, the latter is first soaked in a solution of sodium bicarbonate. In bleaching cotton the goods are boiled in a solution of sodium silicate and then introduced into the perborate bath. In bleaching wool the bath is acidified, preferably by lactic acid. Straw may be bleached by using a perborate solution acidified by oxalic acid. Sodium perborate is perhaps the best agent for bleaching Panama hats. The process is carried out as follows: The hats are washed with warm water and soap, rinsed out well and at once immersed in the bath containing sodium perborate 30 parts and luke-warm water 4,500 parts. The hats are left in the bath for 24 hours. The bath is then heated to 50 to 55 deg. Cent., the hats taken out and transferred to a solution of oxalic acid 30 parts and water 4,500 parts, where they are left for 1 minute, when they are taken out, rinsed and dried in the sun.

Sodium perborate is also used incorporated with soaps, etc., as bleaching and washing agent and as a detergent. A detergent soap is, according to Gressler and Bauer, obtained by incorporating the perborate with ordinary stock soap, either as a powder or mixed with fatty matters (lanoline, vaseline, paraffin) free from glycerine. Silk may be bleached by first washing in soapy water and benzine to remove fatty matter and then introducing into a bath containing 1,000 liters of water, 10 kilogrammes cocoanut-oil soap and 2 to 3 kilogrammes sodium perborate. A substance which may be used for washing, cleaning and bleaching purpose consists, according to U. S. Patent, No. 941,158, of sodium perborate, soda and borax. The most stable preparations are said to be prepared from pure olein soap and sodium perborate. Pe haps the best known preparation of this kind is Henkel's "Persil," said to contain water 31.9 per cent, soda 25.4 per cent, sodium silicate 13.6 per cent, soap 20.1 per cent and sodium peroxide 9 per cent. Even dry oil colors can be removed with preparations of this kind. A good and wholesome hand-cleaning preparation may be prepared by thoroughly mixing 30 parts powdered Castile soap, 3 parts powdered pumice, 45 parts China clay and 22 parts sodium perborate. Sodium perborate is extensively used in Germany for bleaching olive, cotton and linseed oils. It has also been recommended in the manufacture of soluble starch; it is further being u ed for refining gold and silver and for the preparation of artificial incandescent bodies in place of nitrates or chlorates.

A potassium peroxide-perborate of the formulæ $KBO_4.H_2O$ has been obtained by Bosshard and Zwicky. The substance is stable and evolves only traces of oxygen on solution in water.

AMMONIUM PERBORATE $(NH_4)BO_3$.

Such a perborate is obtained by adding an excess of hydrogen perborate to a solution of boric acid in ammonia, the temperature being kept below 10 deg. Cent. The perborate is precipitated by the addition of alcohol. The product has the formulæ $(NH_4)BO_3.\frac{1}{2}H_2O$ and contains 18.48 per cent available oxygen.

CALCIUM PERBORATE.

A calcium perborate is obtained by treating an aqueous solution of a calcium salt with sodium metaborate in the presence of hydrogen peroxide. It may also be prepared by decomposing a calcium salt with an alkali perborate, using but very little water or only the water of crystallization, in order to prevent dissolution of the two salts. Thus, according to R. Gruter, a stable calcium perborate may be obtained by treating sodium perborate with calcium chloride. According to a recent patent[15] a calcium-aluminium perborate containing active oxygen is prepared by dissolving aluminium chloride and boric acid in a hydrogen peroxide solution and precipitating the double perborate with caustic lime. The reaction of this substance is less alkaline than that of the sodium perborate.

An aluminium-sodium perborate is prepared according to a German patent by dissolving 16.6 kilogrammes pure sodium aluminate in hot water, cooling and filtering; then 5 kilogrammes boric acid is stirred into 30 kilogrammes hydrogen peroxide (10 per cent) and added gradually to the first solution. The substance thus obtained is a white, soft powder having the formulæ $Al_2Na_2B_2O_9.5H_2O$ and contains 7 to 8 per cent active oxygen.

Magnesium and zinc perborates are obtained in similar manner as the calcium salt by treating the salts of these metals with sodium metaborate in the presence of H_2O_2. Or boric acid is stirred into a solution of a magne sium or zinc salt, and while the solution is kept in agitation sodium peroxide is introduced, cooling being resorted to if necessary. The perborates obtained as a precipitate are first dried in the air and afterward in a drying oven. They contain 10 to 11 per cent available oxygen. The perborate of calcium, magnesium and zinc are being used in therapeutics and also as bleaching agents. According to a recent German patent fabrics (especially vegetable fibers) are bleached with the aid of magnesium perborate by treating the goods with the perborate in the presence of soap, turkey-red oil or the like, if necessary under pressure. Calcium or magnesium perborates in combination with bicarbonates or phosphates form excellent tooth powders and polishing powders. On moistening with water oxygen is set free and at the same time finely divided carbonate or phosphate is formed. Zinc perborate is superior to hydrogen peroxide as a dressing for wounds. Mixed with starch or talcum it forms an excellent dusting powder; by the addition of zinc perborate to petrolatum a good face cream is obtained. A combination of zinc perborate and tannic acid is used in Europe as a skin bleach.[16] Zinc and magnesium perborate are more stable than the corresponding peroxides and can be kept unaltered for an indefinite period.

PERCARBONATES.

Alkali percarbonates have of late been prepared and are used as oxidizing and bleaching agents. The potassium salt is mostly used; it was for the first time prepared by Constam and von Hansen.[17] It is obtained by electrolyzing a solution of potassium carbonate at 15 deg. Cent., using a current of 5 volts. The percarbonate separates out at the anode as a bluish-white salt. In the dry state it is white. It is hygroscopic which fact limits its use for technical purpose. In water at 0 deg. Cent. it is soluble without decomposition, but it readily gives up its oxygen on contact with water at ordinary temperature. The sodium and ammonium salts behave similarly. With acids these percarbonates form carbon dioxide oxygen and hydrogen peroxide (in small quantity); with caustic lyes, oxygen only. They are powerful bleaching agents but have as yet found but little industrial application as such, as their manufacture is still too costly and cumbersome. Percarbonates of the formulæs $Na_2CO_4.1\frac{1}{2}H_2O$; $Na_2CO_4.\frac{1}{2}H_2O$; $K_2CO_4.3H_2O$ and $Na_2CO_4.8H_2O$ have been obtained. Merck also describes a basic percarbonate of the formula $4Na_2CO_4.H_2CO_3$. An alkali peroxide carbonate is obtained by the interaction of sodium bicarbonate and barium peroxide hydrate:

$$Ba(OH)_4+2NaHCO_3=BaCO_3+Na_2CO_4+3H_2O.$$

Products obtained by the action of hydrogen peroxide on alkali carbonates are, however, not true percarbonates, but appear to be carbonates with hydrogen peroxide of crystallization.[18] By treating fatty acids with molecular proportions of alkali percarbonates at the temperature of a boiling water bath, R. Wolffenstein obtained soaps containing active oxygen. Alkali percarbonates have found application in photography in oxidizing the last traces of "hypo" on plates and paper.

A barium percarbonate is obtained by passing carbon dioxide through an aquous solution containing barium dioxide in excess: $BaO_2+CO_2=BaCO_4$.

PERSULPHATES.

Salts of the persulphuric acid (mono persulphuric or so-called Caro's acid) have lately been used as oxidizing agents and also for the production of hydrogen peroxide of high concentration. They were for the first time prepared by Hugh Marshall and were later studied by Elbs and Schönherr.[19] These persulphates are prepared by electrolyzing a cold saturated solution of the sulphates, using a high-current density and a potential of about 15 volts. The salt separates out on the anode.

Ammonium persulphate $(NH_4)SO_4$ is the only persulphate so far employed for technical purposes. It forms white crystals and in the dry state remains stable up to 100 deg. Cent. At higher temperature it is decomposed, forming oxygen and pyrosulphate. One part of the persulphate is soluble in two parts of cold water; it is but very slowly decomposed by the latter:

$$(NH_4)_2S_2O_8+H_2O=2(NH_4)HSO_4+O.$$

The property which it possesses of oxidizing many aromatic bodies to the corresponding hydroxyl derivates has found technical application. In photography it is employed as a reducing agent. Ammonium persulphate in 1 to 2 per cent solution has powerful disinfecting properties; cholera and other germs are killed in a few minutes. It has also been successfully employed for the preservation of fresh fish. Friedländer[20] states that 1 per cent sodium persulphate prevented putrefaction in broth and wine, that 0.2 per cent was fatal to cholera bacilli and that 0.5 per cent destroyed most other bacteria. It may be used in affections of the mouth and throat as a substitute for potassium chlorate, and in 3 to 5 per cent solutions is a powerful antiseptic for wounds. Sodium persulphate is also an excellent stimulant for failing appetite. An aqueous 1.3 per cent solution for this purpose is known in France as "Persodine."

Wiedeman[21] has patented a process for the manufacture of bleached soaps which consists in adding alkali salts of the persulphuric acid to the ingredients of the soap after the beginning of the saponification and before the end of the saponification. Alkali persulphates are also used for converting starch into the soluble form. A mixture containing potassium persulphate 27 parts, quicklime 20 to 30 parts, potassium chlorate 25 to 35 parts and pyrolusite 20 parts has been recommended for the production of oxygen on a small scale.[22] The reaction is started by the addition of water.

A barium persulphate has been prepared by the interaction of sulphur trioxide on barium peroxide.

Prof. E. P. Alvarz[23] has also studied the pernitrates, perphosphates, perarseniates, pertungstates and perphosphortungstates. They are obtained by the action of sodium peroxide on the alkaline salts of nitric, phosphoric, arsenic, tungstic and phospotungstic acids. All the alkali persalts are white solids. They seem calculated to play an important part in medicine, chemical analysis and in the arts and industries. The pernitrates yield 15 to 16 per cent oxygen by the action of heat (in addition to what they yield as nitrates), are very readily ignited and, therefore, of service in the manufacture of explosives. The perphosphates liberate 13 to 14 per cent oxygen by the action of water and may become of signal use in medicine.

"Pulled" Wool or Shoddy*

By Howard Priestman

It has been well said by a distinguished economist that the trades in which there is most vitality are those which are most flexible in their methods, and the woollen rag trade would appear to be an excellent example of this.

In 1800, 16 million pounds weight of woolen rags were imported into the British Isles; in 1870 the weight was 38 million pounds; in 1880 it was 92 million pounds; in 1912 we (i. e., the British people—Ed.) took from other countries no less than 56,338 tons. This is an amount largely in excess of all the wool grown in these Islands, and it is a fact that is easy of proof, that the proportion of rag wool to raw wool, imported from all parts of the world, has been a steadily increasing ratio during past decades.

How much weight of rags actually goes every year to the pulling machines (or "devils" as they are called) in the neighborhood of Dewsbury there are no figures to show, but there is little doubt that the amount must be well over 200 million pounds weight per year. Contrary to the theory which is usually accepted, that raw materials lose considerably in weight in the manufacturing process, rags gain in weight in their conversion into shoddy. This is due to the large amount of oil that is added to them in the process and if we leave the increase in weight out of account, we find that about four pounds is produced each year, for every man, woman and child in the British Islands. That is to say that every man may have a complete suit of shoddy every year if he chooses, and some must have more than one.

It must be clear to any thinking mind that the use of waste as compared with the destruction of waste is economically advantageous; such a point needs no argument, and economic laws have a way of working in spite of all petty opposition. Indeed the early opposition to the use of shoddy can hardly be described as petty, in anything but the spirit in which it was conceived. It was fierce and long continued. Shoddy was long known as "Devil's Dust." The name was invented by a Mr. Ferrand, an individual who labored with much zeal, much ignorance, and with entire futility to destroy the growing trade of Batley and its neighborhood. But economic laws were working then as they are now, and in obedience to those laws, the Dewsbury and Batley district is now attracting to itself rags from every part of the civilized world, and from some parts that we regard as uncivilized.

[13] English patent 475 of 1910.

[14] German patent 250,074 of 1911.

[15] R. v. Foregger, paper read at meeting of Kings County Medical Society, 1906.

[16] *v. Hölbling, Die Fabrikation der Bleichmaterialien*, p. 214.

[17] *Berl. Berichte*, 1910.

[18] *v. Hölbling, Die Fabrikation der Bleichmaterialien*, p. 212.

[19] *Pharm. Centralhalle*, 1899, p. 102.

[20] U. S. patent 968,438 of 1910.

[21] German patent 244,839 of 1910.

[22] Notes presented at the Sixth International Congress of Applied Chemistry, 1906.

* Reproduced from the *Waste Trade World*.

Before describing the present requirements of the trade, it is necessary that all those who have rags to dispose of should realize that, whatever may have been the case in the past, rags to-day are divided into a vast number of classes. Everything is done and must be done to save unnecessary expense, particularly the expense of redyeing and carbonizing, therefore cotton must be separated from wool, and part cotton from them both, because part cotton rags must be carbonized. All black must go by itself to make a black yarn without being dyed again, and all navy by itself for a like purpose. Soft spun goods must not be mixed with hard, long fibred with short, if the best results are to be obtained.

Let us see what these facts mean to the trade. They have, from very simple beginnings ended in the construction of a complex business system.

Prior to the year 1830 it was the custom of nearly all manufacturers to make what shoddy they required from such rags as they could pick up from the wandering rag and bone man, or as they are called in text books itinerant rag gatherers. It followed as a matter of course that each manufacturer had to deal with all manner of colors and qualities, many of which were of no use to him, and as the trade increased by leaps and bounds a class of small merchants arose in Batley, who bought from the rag men, and did a little sorting and exporting from their native town to places then distant, as Halifax and Huddersfield were before the advent of railways. These middlemen, who really were merchants, began by sorting the rags they bought, but as the demand increased and became more complex, as more and more qualities and shades were required, there appeared room for yet another type of trader between the user, the rag gatherer proper, who goes round from house to house, so that now in addition to that humble and often despised but independent man of business, we have the professional rag dealer, still known as a "marine store dealer" (though he deals in nothing but rags); and again the rag sorter, who in turn sells to the puller or the manufacturer.

In most of the countries from which we import the trade is now organized on somewhat similar lines, and merchants in the heavy woollen district probably buy from some one equivalent to our shoddy or rag dealer. On the other hand some big pullers buy direct from foreign merchants, and although they usually pull the material (that is, reduce the rags to fibre) themselves, there is no trade etiquette to prevent their selling any stocks they may hold, just as they come to hand, either to other pullers, or to merchants who are for the moment short of stock, or in need of some special type.

There is no hard and fast distinction as to who is buyer and who is seller, a state of affairs which admirably illustrates the meaning of the economist's term of "Elasticity," and furthermore, there is a curious resemblance on a much larger scale to be seen when we examine the relations of international markets.

Dewsbury also has its "sales," and just as London is the Mecca of the wool buyer, so is Dewsbury the Mecca for him who deals in rags.

The Dewsbury sales are held by several firms of brokers, whose primary duty it is to sell by auction for a foreign or country client to a home consumer (manufacturer or puller), or to a local merchant. This is done for a small commission.

In one other respect is this trade widely different from the kindred trade in wool. There is little trade on "commission." It may be that the great cost of stocking a worsted factory has broken that trade into small sections, and made owners (large and small) into commission combers, commission spinners, or commission weavers, as the case may be, who comb, spin, and weave the materials sent to them by others, which they never own themselves.

In Batley, firms who exist to do work in this way are few and far between. It is true that some large pulling houses will do pulling on commission for others in the trade, if they happen to be slack. They may carbonize on commission, or even card; but such incidents should be regarded rather as amenities undertaken for mutual convenience, than as trade institutions, as such require no further exposition.

Why pulling differs from other branches it is hard to say, for while there are only two firms that regularly advertise themselves as pulling on commission and doing nothing else, there are well-known firms who have carbonizing plants, who never own the material that they treat, just as there are firms in Bradford who carbonize wool for others.

In spite of the fact that the destruction of any type of waste product or by-product must be economic loss to the community, there are still people to be found who object to the use of shoddy for any purpose, and anyone with ears to hear may hear the word shoddy used as a term of reproach, even in Yorkshire to-day.

Now, as far as this country is concerned, Yorkshire, or to be more particular the district of which Batley is the centre, has almost a monopoly in the transformation of woollen rags into shoddy, and it is therefore the more curious that a trade which brings such an immense amount of money to the country should still be regarded there with any signs of disfavor. This is of course not only a sign of ignorance, but it is the result of ignorance as well, and it really looks as if the inhabitants of neighboring districts who love to speak contemptuously of Batley and all its work, remain in ignorance by choice.

Let it be said at the outset that the writer was born and bred in a worsted district, and brought up to the worsted trade. Nevertheless, he regards the shoddy trade as a marvel of ingenuity, a trade in which each pound of yarn requires more individual thinking on the part of the manager, than is the case in the worsted trade itself.

The shoddy trade is in fact a clever as well as a very "elastic" trade, and there is no better way to make this clear than to make oneself acquainted with the uses and destiny of woollen rags. First let us get our terms in order.

Shoddy is the fibrous material which results when unmilled cloths such as serge, cashmeres, hosiery, the like are "pulled," that is to say, when they are beaten so hard by the pegs in the "Devil" that they break up into their constituent fibres. This must not be understood that fibres after they are pulled are similar to what they were soon after they came from the sheep's back. In the first place, most of them are dyed, in the second many of them are broken, and therefore much shorter than they were originally, thirdly they are worn. The natural roughness of the surface is not always in its original condition, and where the serrations have been badly damaged in the process, spinning power is very often again diminished thereby.

Mungo, as opposed to shoddy, is the product of cloths which were milled in their first existence. In other words, it is made from old dress cloths, old dress uniforms, waiters' clothes and any other dress (woollen) face fabrics. Mungo is shorter than shoddy for two excellent reasons. In the first place there are few exceptions to the rule that woollen cloths are milled and worsted cloths are not. Woollen also consists of shorter fibred material than worsted. The reasons for its shortness of staple are therefore two-fold, firstly, because the cloths from which it is made were themselves made originally from short wool, secondly, because the fibres are so tightly bound or felted together in the milling process that most of them are badly broken before they can be separated again.

Extract is a third class of pulled or disintegrated rags. It is made from fabrics, either milled or unmilled, that have originally consisted of both cotton and wool. These rags have all their cotton "extracted" from them by any of the various carbonizing processes. They are sold in a condition of absolute freedom from cotton, but the acid and the heat of this process leave their mark on the fibres, and it is seldom that they are passed off in the same category as products of pure wool cloths.

The term extract was one which I heard frequently when I was in Huddersfield and Ossett, that is to say, it was a term in regular use by those who dealt in it. Shoddy and mungo, on the contrary, were words that were seldom if ever heard. It may be some deference to old time prejudice that made the woollen trade adopt terms that conveyed more meaning to the initiated. Be that as it may, shoddy made from worsted is not now sold in Batley as shoddy but as "worsted," and other terms, such as serge, flannel, cheviot, and merino are some of those which bear a very different meaning in adjacent towns.

The Range of Wave Lengths of Electro-Magnetic and Light Waves*

ELECTROMAGNETIC waves are now known to us of all wave lengths over a range of many octaves. When Hertz first obtained the electro-magnetic vibrations predicted by Maxwell in his theory of light, there was a vast gap between the wave-lengths corresponding to the frequencies of his oscillators and those of visible light, the former being something like a million times the latter. This gap has now been narrowed until it can be said to have been abolished. On the one hand, the investigation of the spectrum of light from hot bodies has been pushed far into the infra red, heat waves of longer and longer wave-length being discovered by means of a radio-micrometer. These long waves are isolated by different methods, such as continued reflection on a surface of rock salt or slyvite or by making use of their strong refraction by quartz; their wave-length may be found by interferometer methods. In this way, Rubens and Wood have been able to show the existence of heat waves as long as 1/10 millimeter in the radiation from a Welsbach burner.

On the other hand, by the use of improved forms of oscillators, very much shorter electro-magnetic waves have been got than those which Hertz investigated. The shortest waves as yet obtained have a wave-length of 2 millimeters. Thus there is hardly any gap left in the spectrum and one may now say that all wave lengths greater than those of visible light are at our command.

The wave-length of visible light lies between 4×10^{-5} centimeters and 7×10^{-5} centimeters and the known range of the spectrum extends on the other side to the smaller waves composing ultra-violet light, the region investigated photographically. Here waves as short as 1×10^{-5} centimeters have been found by Schumann and are named after the discoverer. Until quite recently the spectrum as known to us has ended at this wave-length.

However, the experiments performed by Messrs. Friedrich, Knipping and Laue have opened up a vast new range in the spectrum never explored before. The paper in which they announce their results appeared in June, 1912, in the proceedings of the Royal Bavarian Academy of Science. The effects which they obtain can only be ascribed to waves of a length of the order of one hundred millionth of a millimeter, the wave-length being small compared with the accepted radius of an atom![1]

* Extract from a paper by Prof. Bragg in *Science Progress*.

[1] The radius of the hydrogen molecule is estimated at eight one hundred millionths of a millimeter.—EDITOR.

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